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JOURNAL

OF THE

American Society of Naval Engineers.

PUBLISHED QUARTERLY

UNDER THE SUPERVISION OF THE COUNCIL.

VOLUME XI.

COUNCIL:

Chief Engineer H. Webster, U. S. Navy.

Chief Engineer A. B. Willits, U S. N.

Passed Ass't Eng'r C. A. E. King, U. S. N.

Passed Ass't Eng'r W. W. White, U. S. N.

Passed Ass't Eng'r Emil Theiss, U. S. N.

WASHINGTON, D. C.

R. Beresford, Printer, 618 F Street, N. W.

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American Machinist.....168 Fulton street, New York.
American Shipbuilder.....7 Coenties Slip, New York.
American Society of Mechanical Engineers.....12 West 31st street, New York.
Army and Navy Journal.....240 Broadway, New York.
Army and Navy Register.....National Theater Building, Washington, D. C.
Association Technique Maritime.....8 Place de la Bourse, Paris, France.

Building, Engineering and Mining Journal, Sun Building, Queen street, Melbourne, Australia.

Cassier's Magazine.....World Building, New York.

Electrical World.....253 Broadway, New York City.
Engineering.....35 Bedford street, Strand, London, England.
Engineering Magazine.....120–122 Liberty street, New York.
Engineering News.....St. Paul's Building, 220 Broadway, New York City.
Engineer's Gazette.....No. 4 Pilgrim street, London, E. C., England.

Franklin Institute.....Philadelphia, Pa.

Institution of Civil Engineers.....Great George street, Westminster, London, S. W., England.

Journal of the United States Artillery.....Fort Monroe, Va.

Literary Digest.....30 Lafayette Place, New York.

Marine Engineering.....World Building, New York.
Marine Journal.....24 State street, New York.
Marine Record.....144 Superior street, Cleveland, Ohio.
Marine Review.....516 Perry-Payne Building, Cleveland, Ohio.
"Mechanics,".....430 Walnut street, Philadelphia, Pa.

Naval Institute.....Naval Academy, Annapolis, Md.
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Quarterly Digest of Physical Tests.....1424 N. 9th street, Philadelphia, Pa.

Scientific Machinist.....Cleveland, Ohio.
"Seaboard,".....129 Broad street, New York.
Sibley Journal of Engineering.....Cornell University, Ithaca, N. Y.
Steamship, The.....2 Custom House Chambers, Leith, Scotland.
Stevens Indicator.....Stevens Institute, Hoboken, N. J.

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Technology Quarterly.....Massachusetts Institute of Technology, Boston, Mass.

Western Society of Engineers.....1737 Monadnock Block, Chicago, Ills.

Yacht le .....55 Rue de Chateaudun, Paris, France.
Yale Scientific Monthly..... .....New Haven, Conn.

Zeitschrift des Vereines Deutscher Ingenieure..... .....80 Wilhelmstrasse, Berlin.

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Illinois Steel Co. Library.....South Chicago, Ill.

Judge, Jno P.....General Electric Co., 227 E. German street, Baltimore, Md.

Kühl, W. H., Bookseller.....72 Jaegerstrasse, Berlin, W., Germany.

Manning, Maxwell & Moore .....111 Liberty street, New York.
Manufacturers' Advertising Bureau and Press Agency.....126 Liberty street, New York.
Maruya, Z. P. & Co.....Tokio, Japan.
Mertvago, Capt. D. T., I. Russian Navy, Naval Attaché, 818 18th st., N. W., Washington, D. C.

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Narita, K., Commander, I. J. Navy.....Imperial Japanese Legation, Washington, D. C.
Naval Engineer Examining Board.....Room 5, P. O. Building, Philadelphia, Pa.
Navy Department Library..... Navy Department.
Newport News Shipbuilding and Dry Dock Co .....Newport News, Va.
New York Public Library.....40 LaFayette Place, New York.
New York Yacht Club.....67 Madison avenue, New York.
North, Francis S., Student.....26 Walton Place, Chicago, Ills.

Odero, N. & Co., Ship and Engine Builders.....Foce, Genoa, Italy.

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Paul, Geo. H., Second Assistant Engineer, U. S. R. C. S.
Peters, Chas. G......The Corners, E. Williston, Long Island, N. Y.
Piper, A. E......The Admiralty, Whitehall, London, S. W., England.
Powel, H. C......3 Winn Road, Lee, Kent, England.

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Sakamato, T., Captain, I. J. N.....Care Kaigun-Daigako, Tsukiji, Tokio, Japan.
Steiger, E. & Co.....Newspaper Box 298, New York.
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University of Michigan Library.....Ann Arbor, Mich.

Van Duzer, Louis S., Lieutenant, U. S. N.

Wardwell, J. E......Superintendent's Office, Treasury Department.
Whittaker, M. M......P. O. Box 77, Newport News, Va.

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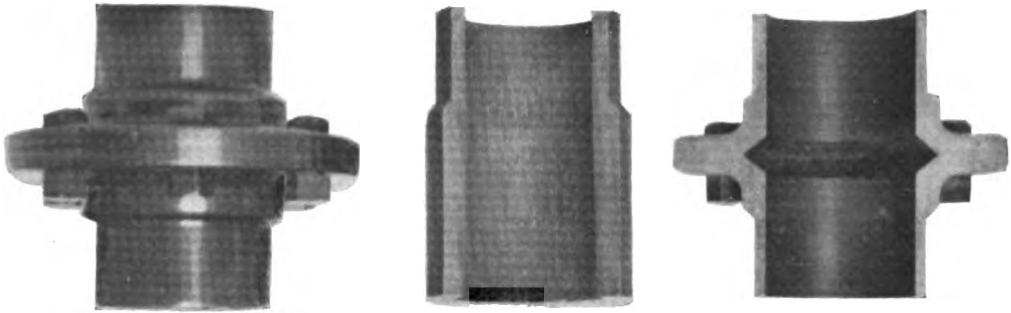

FIG. 4.

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JOURNAL

OF THE

AMERICAN SOCIETY OF NAVAL ENGINEERS.

VOL. XI. FEBRUARY, 1899. No. 1.

The Society as a body is not responsible for statements made by individual members.

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RECENT ADVANCES IN THE MANUFACTURE OF HIGH-GRADE BOILER AND PIPE MATERIAL.

It appears that, what in the mechanical world's progress may be called suddenly, marine engineers have decided that high pressures at sea are no longer to be "downed" by reason of mechanical difficulties in handling them. Thus at almost the stroke of the bell the cumbrous Scotch boiler is swept into the category of the old style, and the lighter water-tube boiler, with its practically limitless possibilities in way of providing steam at any desired pressure and within the shortest possible time, comes in with an initial jump of 100 pounds per square inch over the upper limit of our recent custom. That we should now design for 250 pounds in the boilers to be reduced to 200 pounds at the engine does not appear to be half as much of an innovation as did the use of steam at 100 pounds when our first compound engines came into use twenty years ago, and prior to which the gage needle of our navy boilers seldom passed the 50 mark.

Increase of pressures brings properly a demand for the very best material with which to construct the boilers. *Reliability* is

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the desideratum, as no element of the construction can be defective without imperiling the whole, and with it jeopardizing the lives of those in charge of the plant.

Of late years, and indeed ever since mild steel set out to replace wrought iron, there has been continuous and rapid progress in the art of manufacturing this material, until any desired quality can be uniformly produced by the most careful makers. Undoubtedly the Government inspections and the tests that have been imposed by the Bureau of Steam Engineering, for all material before acceptance, has wonderfully assisted in the advances in the art of steel producing in this country. It has stimulated a beneficial rivalry that has resulted in almost entirely eliminating the elements of unreliability and non-uniformity from the forged steel of to-day. And even with cast steel there is little left to find fault with.

Comparatively recently nickel steel, which has for years been extensively used in armor, has been attracting considerable notice as being most admirably adapted to parts of boiler work, especially to bracing and rivets, and through the patriotic interest of some of our manufacturers we have had tests made which are as valuable as they are interesting. One of these series was published in the last issue of the JOURNAL from notes by Mr. Manusel White, and referred to the excellence of nickel-steel rivets, which with a tensile strength of over 75,000 pounds per square inch, and an elastic limit of over 40,000 pounds, enable us to use a much smaller rivet, cutting away much less of the original plate for the holes. As Mr. White noted, they have quite a fair range of heat at which they can be safely driven, the precaution being not to go above a bright cherry red. These rivets proved to be tougher and freer from the brittleness of heads formed by sledge and cup set, which sometimes appears with common steel rivets.

As to nickel-steel for boiler braces and rods, there is a certain superiority quite as definite as with the rivets. In figure 1 a test piece of this material is shown leaning over the section of pipe, the ends showing the fracture and reduction due to breaking it in the testing machine. This material had the following charac-

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FIG. 1.

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teristics, chemical composition: Carbon, .23; sulphur, .017; manganese, .61; nickel, 3.22, and phosphorus, .021.

Its average tensile strength is over 80,000 pounds per square inch, with elastic limit of over 55,000 pounds per square inch, and an elongation of more than 23 per cent. in 8 inches, the accompanying reduction of area being 55 per cent. This material is very uniform and exceedingly reliable, being as tough as steel can be made. When subjected to a drop test it tears a grain at a time, holding together during many blows after fracture begins. In several cases where bars of this composition *four* inches diameter have been tested by dropping a weight of 1,640 pounds upon them from a height of forty-four feet, the bars being supported at their ends only, and after each drop the bars being turned over to put the convex part of the resultant bend always uppermost, it required forty blows of this nature *before fracture begun*, and forty additional blows to complete the break.

Comparing the specifications of even ten years ago, shows the care with which the inspection work has been supervised, and the safeguards with which it has been surrounded to the almost certain exclusion from use of anything but the very best material. Take, for instance, the specifications for steel for the *Maine's* boilers in 1888.

BOILER PLATES.

"24. Boiler plates, shapes, braces and rivets must not show more than .03 of 1 per cent. of phosphorus; all other steel material not to show more than .06 of 1 per cent. of phosphorus.

"26. One tensile test piece shall be cut from each plate as rolled for boilers, either longitudinally or transversely, as directed by the Inspector, and one piece to be used as a bending piece.

"27. *Tensile tests of shell plates.*—Transverse specimens must show a tensile strength between 58,000 and 67,000 pounds, with an elongation of at least 22 per cent. Longitudinal specimens must show a tensile strength between 58,000 and 67,000 pounds, with an elongation of at least 25 per cent. The elastic limit must be at least 32,000 pounds per square inch.

"28. *Tensile tests of furnace and flange plates.*—Test pieces

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must show a tensile strength between 50,000 and 58,000 pounds, with an elongation of 26 per cent. either longitudinally or transversely.

"29. *Cold-bending test.*—One piece to be cut from each shell plate as finished at the rolls for cold-bending test, which must bend over flat on itself without sign of fracture.

"30. *Quenching test.*—One piece shall be cut from each furnace or flange plate as finished at the rolls for quenching test, and after heating to a cherry red, plunged into water at a temperature of 82° F. Thus prepared, it must be possible to bend the piece so that it shall be doubled round a curve of which the diameter is not more than one and a half times the thickness of the piece tested, without showing any cracks. The ends of the pieces must be parallel after bending. Quenching and cold-bending pieces must not have their sheared or planed sides rounded off, the only treatment permitted being taking off the sharpness of the edges with a fine file.

"31. *Surface inspection.*—Plates and shapes must be free from slag, foreign substances, brittleness, laminations, sand or scale marks, scabs, snakes, pits and surface defects generally. Shapes must also be free from defective sections, shaded back, grooved fillets, &c.

"32. *Shearing.*—Boiler plates $\frac{13}{16}$ of an inch thick and over shall not be sheared closer to finished dimensions than once the thickness of the plate at each end and one-half the thickness of plate along each side.

TESTS FOR BOILER RIVETS.

"33. Steel for rivets must be made by either the ordinary open-hearth or Clapp-Griffith process.

"34. Each ton of rivets from the same heat or blow shall constitute a lot. Four specimens for tensile tests shall be cut from the bars from which the lot of rivets is made.

"35. *Tensile tests.*—The rivets to be driven by power shall be from 58,000 to 67,000 pounds tensile strength, with an elongation of not less than 26 per cent.; and those to be driven by hand shall have a tensile strength of from 50,000 to 58,000 pounds, with an elongation of not less than 30 per cent.

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"36. *Hammer test.*—From each lot twelve rivets are to be taken at random and submitted to the following tests:

"37. Four rivets to be flattened out cold under the hammer to a thickness of one-half the diameter without showing cracks or flaws.

"38. Four rivets to be flattened out hot under the hammer to a thickness of one-third the diameter without showing cracks or flaws—the heat to be the working heat when driven.

"39. Four rivets to be bent cold into the form of a hook with parallel sides without showing cracks or flaws.

MATERIAL FOR STAY-RODS AND BRACES.

"40. Two tons of material for boiler braces, from the same heat, shall constitute a lot from which one tensile test piece shall be taken.

"41. *Tensile test.*—Bracing coming into contact with the fire to have a tensile strength of from 50,000 to 58,000 pounds, and an elongation of not less than 26 per cent. Other bracing to have a tensile strength of not less than 65,000 pounds and an elongation of not less than 24 per cent.

"42. *Bending test.*—Bars one-half ($\frac{1}{2}$) inch thick, cut from the bracing coming into contact with the fire must stand bending double to an inner diameter of one and one-half ($1\frac{1}{2}$) inches after quenching in water at a temperature of 82° F., from a cherry-red heat, without showing cracks or flaws. Similar pieces cut from the other bracing must stand cold-bending double to an inner diameter of $1\frac{1}{2}$ inches."

And then compare this with the specifications for inspection of boiler material in 1898, for torpedo boats, destroyers, monitors and battleships now under construction.

BOILER PLATE. (CLASS A.)

"1. The inspection must conform to the 'General Instructions' for the inspection of material coming under the cognizance of the Bureau of Steam Engineering.

"2. The failure of a large proportion of the material inspected to stand the specified tests in a satisfactory manner will render the whole delivery liable to rejection.

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"3. *Kind of material.*—Steel for boiler plates shall be made by the open-hearth process, and not show more than thirty-five one-thousandths ($\frac{35}{1000}$) of one (1) per centum of phosphorus nor more than three one-hundredths ($\frac{3}{100}$) of one (1) per centum of sulphur, and be of the best composition in other respects.

"4. *Test specimens.*—One tensile-test piece, taken longitudinally, and one bending test piece, taken transversely, shall be cut from each plate as rolled for boilers, as directed by the Naval Inspector. The cold-bending pieces must not have their sheared nor planed sides rounded off, but the sharpness of the edges may be taken off with a fine file.

"5. *Tensile tests of Class A No. 1 Plates.*—Test specimens must show a tensile strength between 74,000 and 82,000 pounds per square inch, with an elastic limit of 40,000 pounds per square inch, and an elongation of at least twenty-one (21) per centum in eight (8) inches.

"6. *Tensile tests of Class A No. 2 Plates.*—Test specimens must show a tensile strength between 66,000 and 74,000 pounds per square inch, with an elastic limit of at least 32,000 pounds per square inch, and an elongation of at least twenty-three (23) per centum in eight (8) inches.

"7. *Tensile tests of Class A No. 3 Plates.*—Test specimens must show a tensile strength between 60,000 and 66,000 pounds per square inch, with an elastic limit of at least 36,000 pounds per square inch, and an elongation of at least twenty-five (25) per centum in eight (8) inches.

"8. *Cold-bending test.*—One specimen, cut from each Class A No. 1 and Class A No. 2 Plate, as finished at the rolls for cold-bending test, shall bend round a curve the diameter of which is equal to the thickness of the plate tested till the sides of the specimen are parallel, without signs of fracture on the outside of the bent portion.

"9. *Cold-bending tests.*—One specimen, cut from each Class A No. 3 Plate, shall bend flat on itself without signs of fracture on the outside of the bent portion.

"10. *Inspection for surface and other defects.*—Plates must be free from slag, foreign substances, brittleness, laminations, hard

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spots, injurious sand or scale marks, scabs, snakes, and injurious defects generally.

"11. *Shearing.*—Boiler plates, thirteen-sixteenths ($\frac{13}{16}$) of an inch thick and over, shall not be sheared closer to finished dimensions than once the thickness of the plate along each end, and one-half the thickness of the plate along each side. This allowance shall be made by the contractor on his order, and the manufacturer shall shear to ordered dimensions.

"12. *Weight and gage.*—Contractors shall enter on their orders to manufacturers both weight per square foot and gage of plates. Plates shall not vary from the specified weight more than the following amounts: Two (2) per centum below and seven (7) per centum above for plates more than one hundred and ten (110) inches wide; two (2) per centum below and six (6) per centum above for plates between one hundred (100) and one hundred and ten (110) inches wide; two (2) per centum below and five (5) per centum above for plates between eighty (80) and one hundred (100) inches wide; two (2) per centum below and four (4) per centum above for plates between sixty (60) and eighty (80) inches wide; and two (2) per centum below and three (3) per centum above for plates less than sixty (60) inches wide.

"13. *Gage.*—No plate must, at any point, fall below the specified thickness more than the following amounts: Six one-hundredths ($\frac{6}{100}$) of an inch for plates more than one hundred and ten (110) inches wide; five one-hundredths ($\frac{5}{100}$) of an inch for plates between one hundred (100) and one hundred and ten (110) inches wide; four one-hundredths ($\frac{4}{100}$) of an inch for plates between eighty (80) and one hundred (100) inches wide; three one-hundredths ($\frac{3}{100}$) of an inch for plates between sixty (60) and eighty (80) inches wide; and two one-hundredths ($\frac{2}{100}$) of an inch for plates less than sixty (60) inches wide.

"14. *Oil tempering and annealing.*—It is left optional with the manufacturers to oil temper and anneal Class A No. 1 Plates of a thickness greater than one (1) inch, in order to get the requirements of these specifications; but the oil tempering and annealing must be done before the plate is submitted to the Naval Inspector for tests.

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"15. NOTE.—The Class A No. 1 and Class A No. 2 Plates must be taken from the tables as soon as finished at the rolls and covered with dry sand or ashes in order that they may cool slowly and evenly, in case they are not regularly annealed in an annealing furnace."

"BOILER BRACING. (CLASS A.)

"3. *Kind of material.*—Steel for stay bolts and braces shall be made by the open-hearth process, shall not show more than thirty-five one-thousandths ($\frac{35}{1000}$) of one (1) per centum of phosphorus, or more than three one-hundredths ($\frac{3}{100}$) of one (1) per centum of sulphur, and shall be of the best composition in other respects. The drillings for chemical analysis shall be taken from the same objects as the tensile-test pieces.

"4. One ton of material for boiler braces, from the same heat, shall constitute a lot from which two tensile and one cold-bending test specimens shall be taken, each from a different object.

"5. *Treatment.*—All material for boiler bracing shall be annealed as a final process.

"6. *Tensile tests of Class A No. 1 Bracing.*—Test specimens must show a tensile strength of at least 74,000 pounds per square inch, with an elastic limit of at least 40,000 pounds per square inch, and an elongation of at least twenty-two (22) per centum in eight (8) inches, or twenty-six (26) per centum in two (2) inches, in case 8-inch specimens can not be secured.

"7. *Tensile tests of Class A No. 2 Bracing.*—Test specimens must show a tensile strength of at least 66,000 pounds per square inch, with an elastic limit of at least 36,000 pounds per square inch, and an elongation of at least twenty-four (24) per centum in eight (8) inches, or twenty-eight (28) per centum in two (2) inches, in case 8-inch specimens can not be secured.

"8. *Tensile tests of Class A No. 3 Bracing.*—Test specimens must show a tensile strength of at least 60,000 pounds per square inch, with an elastic limit of at least 32,000 pounds per square inch, and an elongation of at least twenty-six (26) per centum in eight (8) inches, or thirty (30) per centum in two (2) inches, in case 8-inch specimens can not be secured.

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"9. *Cold-bending test.*—One bar, one-half (½) inch thick, cut from each lot of Class A No. 1 bracing shall stand cold bending double to an inner diameter of one (1) inch, the ends of the piece being brought parallel, without showing signs of fracture on the outside of the bent portion.

"10. *Cold-bending test.*—One bar, one-half (½) inch thick, cut from each lot of Class A No. 2 bracing shall stand cold bending double to an inner diameter of one-half (½) inch, the ends of the piece being brought parallel, without showing signs of fracture on the outside of the bent portion.

"11. *Cold-bending test.*—One bar, one-half (½) inch thick, cut from each lot of Class A No. 3 bracing shall stand cold bending flat on itself, the ends of the piece being brought parallel, without showing signs of fracture on the outside of the bent portion.

"12. *Opening and closing tests.*—Angles, T bars, and other shapes, are to be subjected to the following additional tests: A piece cut from one bar in twenty shall be opened out flat while cold, without showing cracks or flaws; a piece cut from another bar in the same lot shall be closed down on itself until the two sides touch, without showing cracks or flaws.

"13. *Inspection for surface and other defects.*—Stay rods and bracing must be true to form, free from seams, hard spots, brittleness, injurious sand or scale marks, and injurious defects generally.

"14. Boiler plate used as boiler bracing shall be inspected as plate under the specifications for boiler plate of the class required by the machinery specifications.

"SPECIFICATIONS FOR RIVET RODS AND FINISHED RIVETS.

"3. *Kinds of material; High grade and Class A rivet round* shall be made by the open-hearth process; shall not show more than thirty-five thousandths of 1 per cent. of phosphorus, nor more than three-hundredths of 1 per cent. of sulphur; and shall be of the best composition in other respects. The drillings for chemical analysis shall be taken from the cold-bending test specimens.

" *Class B rivet rounds* may be made either by the open-hearth

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or Bessemer process, and shall be used in all Class B material and may be used in other material if permitted by the Machinery Specifications.

TENSILE AND BENDING TESTS TAKEN FROM THE RIVET RODS.

(To be tested in the full size of the rods when possible.)

"4. *Test specimens.*—If the total weight of rods rolled from a heat amounts to more than six tons, then the Naval Inspector shall select, at random, six tensile-test pieces, three cold-bending test pieces, and three quenching-test pieces, each from a different rod. If the total weight of rods rolled from a heat amounts to less than six tons, then the Naval Inspector shall select, at random, one tensile, one cold-bending, and one quenching-test piece for each ton or part of ton, each from a different rod. If only one of these rods selected for test fails, the Naval Inspector shall select another rod from the same lot and put it through the same test as the one that failed; and if it is found satisfactory he shall pass the lot. The tensile test of sizes of rounds under five-eighths of an inch in diameter shall be made on rounds of five-eighths of an inch in diameter.

"5. *High-grade rivet rods*, of nickel steel, shall have from 75,000 to 85,000 pounds per square inch tensile strength, with an elastic limit of at least 40,000 pounds per square inch, and an elongation of at least 23 per cent. in eight inches.

"6. *Class A, rivet rods*, of open-hearth steel, shall have from 60,000 to 68,000 pounds per square inch tensile strength, with an elastic limit of at least 32,000 pounds per square inch, and an elongation of at least 26 per cent. in eight inches.

"7. *Class B, rivet rods*, of open-hearth or Bessemer steel shall have from 54,000 to 62,000 pounds per square inch tensile strength, with an elastic limit of at least 30,000 pounds per square inch, and an elongation of at least 29 per cent. in eight inches.

"8. *Cold-bending test.*—The specimen shall stand cold bending double to an inner diameter of one-half inch without showing cracks or flaws on the outside of the bent portion.

"9. *Quenching test.*—The specimen shall, after heating to a

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dark cherry red, in daylight, be plunged into water of a temperature of 82° F., and shall then stand bending double to an inner diameter of one-half inch without showing cracks or flaws on the outside of the bent portion.

"HAMMER TESTS ON FINISHED RIVETS.

"10. *Hammer tests.*—For each ton in weight of finished rivets, made from the same heat, four rivets shall be selected, at random, by the Naval Inspector and submitted to the following tests:

"(*a*) One-half of these specimens of each size to be flattened out cold under the hammer to a thickness of one-half the original diameter of the part flattened without showing cracks or flaws.

"(*b*) One-half of these specimens of each size to be flattened out hot under the hammer to a thickness of one-third of the original diameter of the part flattened without showing cracks or flaws; the heat to be the ordinary working heat of rivets when driven.

"11. *Inspection for surface and other defects.*—Rivets shall be true to form, concentric, and free from injurious scale, fins, seams, and all other injurious defects."

SPECIFICATIONS FOR THE INSPECTION OF SEAMLESS COLD-DRAWN BOILER TUBES OF STEEL.

"1. The inspection must conform to the 'General Instructions for the Inspection of Material coming under the cognizance of the Bureau of Steam Engineering.'

"2. These tubes will be made of low-carbon mild steel, of the best composition for the purpose, and uniform in quality and grade. The Naval Inspector will take drillings for chemical analyses.

"3. The tubes will be inspected for surface defects after being straightened, but before being cut to length, and they must be free from rust, scale, sand marks, laminations, hard spots, checks, cracks, and injurious defects generally.

"4. The pointed end of the tubes will then be cut off, trimmed, and gaged, and each tube at the thinnest point must be up to

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the gage ordered. The interior of each tube will be inspected at the same time, and any that are badly seamed or scratched in the drawing will be rejected.

"5. The tubes which have passed the above inspection will then be cut to the lengths ordered and gaged at the end last cut off, and each tube at the thinnest point must be up to the gage ordered. A sufficient number of test tubes, selected and stamped by the Naval Inspector, will be cut about four inches longer than ordered.

"6. If the tube ends are flanged, swedged down, swelled, upset, or reenforced, they will be inspected afterwards to see that no material damage has been done by this process.

"7. Each tube shall be subjected to 1,000 pounds internal hydrostatic pressure without showing weakness or defects.

"8. All tubes must be annealed in retorts or an approved furnace in which the flame from the fuel used in heating the annealing furnace does not strike the tubes. One or more of the stamped test tubes will be placed in the center of each retort or middle of each furnace charge, one for each twenty-five tubes or less. The charge of each retort or furnace will be numbered and kept separate until the tests are completed. The test tubes will be given the same number as the charge with which they are annealed, so that if it is found after testing that any lot is not soft enough, it may be reannealed.

"9. The annealed tubes will then be divided into lots of not more than one hundred each, and the Naval Inspector will subject four of the stamped test tubes belonging to each lot to the following tests:

"*a*. The end of one test tube must stand being flattened by hammering until the sides are brought parallel, with a curve on the insides at the ends not greater in diameter than twice the thickness of the metal in the tube without showing cracks or flaws.

"*b*. One test tube shall have a piece 1 inch long cut from the end, which must stand crushing in the direction of its axis, under a hammer, until shortened to ½ inch without showing cracks or flaws.

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"*c.* The end of one test tube, cold, shall have a smooth taper pin, taper 1½ inches to the foot, driven into it until the end of the piece stretches to 1⅛ times the original diameter, without showing cracks or flaws.

"*d.* The end of one test tube, heated to a bright cherry red, in daylight, shall have a smooth taper pin, taper 1½ inches to the foot, at a dull red heat, in daylight, driven into it until it stretches to 1⅛ times its original diameter.

"If any one of these tubes selected for test fails, that tube will be rejected, and the Inspector will select two extra tubes from the same lot and put them through the same test as the tube that failed, and both of these tubes must be found satisfactory in order that the lot may be passed. The failure to pass satisfactorily any of the tests marked *a*, *b*, *c*, *d* will reject the lot.

"10. Each tube will then be separately weighed and accepted up to 8 per cent. above the standard weight for the gage ordered. The standard weight for seamless drawn steel tubes will be 0.283 pound per cubic inch of material.

"Each tube will be stenciled with the name of the vessel for which intended, or with the number of the order.

"11. The failure of a large proportion of the tubes selected to stand any of the above specified tests in a satisfactory manner will render the whole delivery liable to rejection.

"12. All tubes rejected will be marked in such a manner as to prevent their being presented a second time for inspection.

"13. The tube inspector's "Identification Stamp" and the "U.S. Anchor Stamp" shall be put on the cases in which the tubes are shipped. If the tubes are shipped in box cars containing no other freight, the cars must be sealed and the above stamps put on with the seal, and, in this case, it will not be necessary to box or crate the tubes."

Boiler tubes, fittings and steam and water pipes are now, of course, subjected to the increased pressure, and are objects of as much concern regarding their trustworthiness and perfection as is the boiler proper. Steel is the material for these parts best adapted, and the sample section of pipe in Fig. 1 is a lap-welded seven-inch steel steam pipe for torpedo-boat work. The one-

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inch sharp angle flange on the end of this pipe was turned cold without showing any cracks or flaws, and it was afterwards pened to represent the manner in which it would be necessary to treat the metal to put a full flange on it. The seamless-drawn steel piping stands this test even with less risk, as there is no danger in that case of faulty welds, which would surely be discovered in the severe treatment.

In the advances of seamless-drawn pipe making comes a novelty illustrated by Fig. 2, in which is shown the possibility of making both T's and crosses in this manner. As these are necessarily of the very highest grade steel, the advantages they possess over the bulkier and less reliable castings usual to such forms are obvious, and especially for the express type of boiler work where reduction of weight, provided it does not decrease strength or reduce longevity, is most desirable.

The last number of the JOURNAL alluded to the fine surfaces of the solid-drawn tubes. Recent discussions as to what is meant by "solid-drawn" have been published in several of the technical papers. With the Bureau of Steam Engineering the term implies only tubes drawn through dies, from the solid ingot and does not include lap-welded tubes drawn down. The latter may present as fine a surface but the very fact of the possibility of a weld being started by the process and yet undiscernable to the inspector, creates a doubt which is not consistent with the spirit of the specification.

Great improvements have been made in the method of obtaining excellence in the matter of pipe flanges for high pressures, and the results up to the present time have been not only highly satisfactory, but embrace features of novelty and interest as well. With the adoption of steel for high-pressure steam pipes came the necessity of making sure that defects should not develop in the flanges. Not only is the element of danger one to be thus guarded against, but also the issues of economy which are so seriously damaged by leaky joints. The flanges must be substantial, and heavy enough to permit of properly making and holding the junctions of sections and preserving the integrity of the system, and at the same time they must be as nearly a por-

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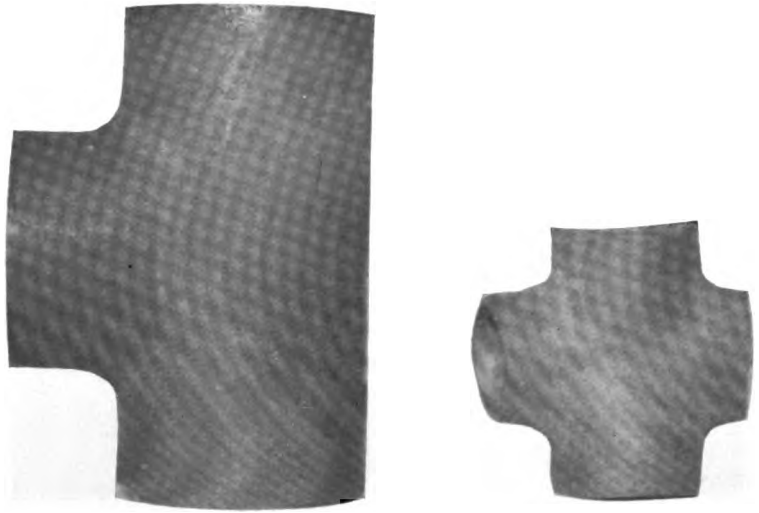

FIG. 2.

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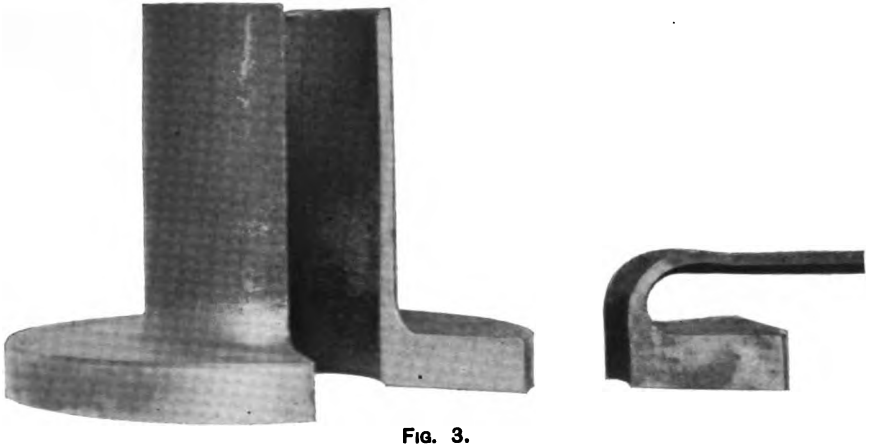

FIG. 3.

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tion of the pipe itself as is possible to make it. Hence the superiority of a perfectly-welded flange over the old brazed and riveted flanges of our lower-pressure copper pipes, or the riveted and calked flanges of wrought-iron pipes. Fig. 3 shows how perfectly this work of welding flanges is now done; and it is applied equally readily to pipes of one inch and as high as thirty inches in diameter. Also there is no necessity of the metal of pipe and flange being alike, as an iron flange can be welded either to a steel or iron pipe. These flanges are cut from a solid plate.

The test here shown was made by cutting a section for a selected pipe as shown in the figure and bending the strips of pipe parallel to face of flange, the *bend* being *in the weld*. The perfection of the weld is thus clearly shown, and with a seamless-drawn pipe and a solid-cut flange there is little room to criticise the result in points of either solidity or finish.

The thickness of pipe desired in order to make the weld properly is given as follows:

Two-inch pipe should be No. 6 B.W.G. thick; 4-inch pipe should be No. 4 B.W.G. thick; 5 and 6-inch pipe should be $\frac{1}{4}$-inch thick; 8-inch pipe should be $\frac{5}{16}$-inch thick.

Pipes can be solid drawn up to 8 inches diameter.

In the matter of flanging, however, there has been produced a more remarkable result than the above with low-carbon steel of finest grade, following the lines of "*spinning*" the metal. This is shown by the three samples in Fig. 4 (frontispiece).

The piece in the middle represents a heavy "upset" two inches long on a No. 8 B.W.G. seamless-drawn boiler tube. The upset end was then swelled, cold, with a taper mandrel, and being placed in a special machine, resembling a lathe, was rapidly revolved, while a former was, by special hydraulic machinery, pressed steadily and powerfully against the expanded end until the metal was heated and spun into the general shape of a flange. It was necessary to cut only one-eighth inch from the edge of this flange to remove absolutely all indications of fraying or cracks, and then the flange end was trued up to give it the finished appearance shown in the two outside pieces in the figure.

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A powerful machine is now under construction by which this character of work will be applied to pipes up to eight inches outside diameter, which includes all the sizes of steam and water pipe now used in torpedo boats and destroyers building for the Government.

A series of tests is now being made on these flanges, using high-grade nickel-steel bolts, to determine just what pressure the flanges will stand. The thickness of flange necessary for each size of piping will be practically determined, and each piece will be tested to rupture, to locate the weak points in the design.

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A DISCUSSION OF PASSED ASSISTANT ENGINEER J. K. ROBISON'S PAPER ON "WATER-TUBE BOILERS A NECESSITY."*

Charles Ward.—No subject has, perhaps, had more consideration and discussion among marine engineers than that of the desirability of water-tube boilers. So much has been said and written upon them that one familiar with the subject would hesitate to write a paper presenting any new features. But Mr. Robison has taken quite an original view of the matter, and given us a very practical side of the question. He has utilized the practical experience with these boilers during the Spanish war, and set forth some very practical deductions which will be carefully considered in our future work and practice.

The very first deduction or assertion in the title of the paper, "Water-Tube Boilers a Necessity," is a source of gratification to those who, like myself, have been struggling for upwards of twenty years to secure the adoption of water-tube boilers for marine use. In connection with this assertion, we may also note that Commodore Melville, in his last annual report, thus expresses himself: "The demands upon the engineer for great power on small weight, in order to secure the higher speeds for all classes of vessels which are now common, have practically ruled out the cylindrical boiler."

In no department of science or branch of engineering has there been more progress than in marine engineering. Vessels designed and built only a very few years ago and still magnificent specimens of the art, would to-day be vastly improved by the application of principles which have evolved in the very few years just passed. The steam pressures of 250 and 300 pounds now considered a necessity in a battleship, would not have had serious consideration three or four years ago; yet to-day most of the

* November JOURNAL, 1898.

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navies of the world are formulating their plans on boiler pressures of 250 pounds and 300 pounds, which, of course, excludes the use of anything but water-tube boilers. So that the title of the paper seems entirely justified, though at first, at least to the old school, quite startling.

To one who has been laboring so long in this direction, it seems strange that the evolution should have been so slow. It is upwards of twenty years since we commenced building marine water-tube boilers. In the year 1882, we placed on a vessel in New York city a water-tube boiler having 85 square feet of grate and 3,000 square feet of heating surface, which was tested on board to 850 pounds hydraulic pressure. The engines, which were to use steam at 500 pounds, were, however, a failure, partly from bad design and partly from want of capital to correct the errors. The engines being condemned, it was decided to test the efficiency of the boiler, and if found satisfactory, to put in new machinery. I was accordingly called upon, in the summer of 1883, to demonstrate by actual test under forced draft and 250 pounds steam pressure, the capacity of this boiler, which had already been condemned by one of the most prominent engineering firms of New York. Mr. W. H. Rodman, then superintending engineer for Mr. John Roach, was called in on behalf of the owners of the vessel. Mr. Rodman reported, after the test, that the boiler had capacity to furnish more steam than the boat could utilize. The steam pressure at that day was more than engine builders cared to handle. At my suggestion, indorsed by Mr. Rodman, it was decided to put in a triple-expansion engine to use steam at 180 pounds to 200 pounds, if I remember rightly. The work was entrusted to the Bath Marine Iron Works, of Bath, Maine. The engine was designed, built and installed, with most satisfactory results, under the direction of Mr. Charles H. Hyde, thereby giving him the distinction of designing and building the first marine triple-expansion engine in America. This vessel was afterwards changed into a yacht, and is now named the "*Golden Rod*," and owned by Archibald Watt, Esq., ex-commodore of the American Yacht Club.

At that time 250 pounds of steam was considered out of the

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question, but to-day, it is an established fact, with a very decided tendency upwards, and who will venture to say where it shall stop? With this change the water-tube boiler has truly become "a necessity." Their use in actual warfare has been tested and many new conditions and requirements developed during the late war, and we are fortunate in having their good qualities and defects so aptly portrayed by the author of the paper, who has pointed out many features to be considered in future designs.

Mr. Robison calls attention to the personnel. This is most important. You may as well be without ships as men to operate them. This applies not only to the men, but also to their qualifications. It is absolutely necessary to increase the personnel with the number of ships, and at the same time maintain its efficiency. An incompetent man is always a most expensive adjunct, and more emphatically so in a position of responsibility on one of our modern ships, which requires men above the average intelligence. I venture to say that much of the expense incurred in repairing the ships' machinery, made necessary by the war, would have been saved if well-trained and efficient service could have been obtained. The efficiency of a war ship is as that of her crew. The time to prepare for war is during peace. It is just as necessary to have carefully-drilled firemen and water tenders as it is to have an efficient army. Who would think of taking green men into the field? Even in our own hurried preparation, the men were assembled, drilled in camp, broken to camp life and then moved in stages to the warmer climate and to active warfare. We have seen the best new boilers ruined by the carelessness and inefficiency of those in charge. We have in mind two boats engaged in the same service, in the same waters, having the same make of water-tube boilers, of the same material and design. One was ruined in two years, while the other was in use between five and six years without any repairs. In another case two large boats, each having four large water-tube boilers of the same design, manufacture and material,—the boilers of one boat needed few repairs, while the other was constantly out of order. After much censure being heaped upon

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the boilers, it was found that changing a part of the crew from one boat to the other, changed the conditions.

Mr. Frank L. Dubosque, the efficient Assistant Superintendent of Floating Equipment of the Pennsylvania Railroad, thus expresses himself at a recent meeting of the Society of Naval Architects and Marine Engineers: "Water-tube boilers are a success, phenomenally so on a great many torpedo boats, and there is no reason why they should be made a failure on any one. I believe the failure of water-tube boilers on any boat is due to neglect, when the boilers are properly designed. We have had personal experience with five different types of water-tube boilers, four of which were of excellent design. On all four, what little trouble has been experienced has been clearly traceable to management. After some little experience, I can say safely that all four of these types are now being operated successfully by the most unskilled labor in the fireroom. Further than that, they are being operated from sixteen to eighteen hours every day of the week and week of the year."

Leaky condensers are a fruitful source of trouble with boilers. I recently saw an excellent water-tube boiler ruined from this cause. The spaces outside the tubes of the boiler were filled solid with salt. Upon investigation it was found that many of the condenser tubes had "crept out," and that an effort had been made to make the tube head tight by plastering with Portland cement. In this case, an inefficient or unprincipled man cost the owners of the vessel three or four years' salary for a most efficient one. This suggests the question whether there is not room for improvements in condensers? whether straight tubes therein are the most satisfactory, even though provision is made for the unavoidable expansion and contraction in the fastenings at the ends? Would the frailties of the condenser be permitted in a boiler? The Engineer-in-Chief, in his last report, says: "Fresh water for the boilers is almost as important as coal." This being so, it is most important especially for water-tube boilers (now a necessity) that the condensers should be perfect. Here I would like to emphasize also the importance not only of fresh water, but as far as possible of clean water, especially free

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from acids and grease, both deleterious; the latter deposited on the interior surface of the boiler reduces its efficiency enormously. This suggests the question, Is the internal lubrication of engine cylinders a necessity? Oil is certainly a very serious nuisance when it reaches the condenser and the boiler. If "necessary," that lubricant least injurious should be used, and with it efficient means to prevent it reaching the condenser or boiler. For this an efficient filter may become also a "necessity." We are, however, at a loss to understand why engines of torpedo boats, which have the *highest piston speed, can be run without oil*, and other craft cannot!

Some two years ago, we were awarded the contract to re-tube the boilers of the torpedo-boat *Cushing*. The removed tubes were absolutely clean inside, although they had been in use some six years. Their condition was highly creditable to the engineer officer in charge, especially when we had just examined a yacht's boiler which had from $\frac{1}{8}$ to $\frac{3}{16}$ deposit of greasy matter on the inside.

I can hardly agree with Mr. Robison when he says, "no great efficiency in firing must be required to attain a good efficiency of the boiler." We think there are few places where efficiency pays better than in the fire room. We feel that this is so important that men should be trained in sufficient numbers to have at least one efficient fireman on each watch in each fire room, during activities like those during the late war, and that it should be his duty to initiate and superintend the green men during time of war, if trained men in sufficient numbers cannot be obtained.

Great trouble was experienced, Mr. Robison tells us, from inefficiency due to dirty fires and lack of opportunity to clean them. I would suggest the use of the highest grade coal. There are coals in this country unsurpassed in the world, and on shipboard none but the purest and best should be used. When coal room is so scarce, why take coal containing from 10 per cent. to 20 per cent. of foreign matter, when there are coals in abundance having not more than $2\frac{1}{4}$ per cent.?

During a test made by a board of naval engineers, of which Commodore Loring was president, a Ward boiler, having sixty-six

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square feet of grate surface, burned fifty-five pounds of coal per square foot of grate for two continuous twelve-hour runs without cleaning fires; as much coal was burned during the last hours as through any of the preceding. At the close of the runs the remaining dry refuse was only 4.8 per cent., including what little coal had fallen through grates in spreading fires. The ashes were not burned as in some tests.

Touching the endurance and efficiency of water-tube boilers, Commodore Melville, in his report, cites the performance of the *Annapolis* and *Marietta*, both of which had been in service more than one year, and yet made excellent showing. I can add to this the performance of the Revenue Cutter *Hudson*, which distinguished herself by saving the disabled *Winslow* and her crew from the enemy's fire. The *Hudson* had been on "boarding duty" in New York harbor for five years, was ordered to the war, made the trip and distinguished herself, and returned to New York without any boiler repairs during six years of service. She certainly has an efficient engineer.

I cannot help regretting that I have not some data of the record of the *Monterey's* trip to Manila. It will be remembered that her boilers were built in 1890, now nine years ago; and she, a coast defense vessel, makes a 6,500 miles trip partly under her own steam.

John I. Thornycroft.—I have read Mr. Robison's paper with much interest, and agree with him in much that he has said, but *not* in the necessity for straight tubes. I think we must look to change in the condenser details to save our fresh water from having accidental additions of sea water.

In ships where the weight of machinery is not quite so important as in the destroyers, perhaps the construction of condenser proposed and used by Loftus Perkins, in which the condensing water was conveyed by one internal tube to near one closed end of the condensing tubes, which were only made fast in a tube plate at the other, would avoid the effects of expansion to cause leakage. Mr. Perkins said that his condensers were perfectly tight, but we are unable to secure this result by the

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modern construction of condensers with straight tubes secured by glands at both ends. I think it is not possible to exactly determine where each part of the loss of fresh water takes place in a ship, but the safety valves are responsible for much, also the drainage of the many steam pipes, is imperfectly collected. The loss in the boilers should be very small, in externally-fired boilers with curved tubes of iron or steel, for in them the tube joints keep perfectly tight, and a considerable amount of sea water may be used without causing sufficient internal deposit to make it necessary to clean the inside of the tubes. Salt water, however, tends to cause corrosion of the generating tubes, and every effort should therefore be made to keep it out entirely, as corrosion is at present the greatest difficulty to be overcome with water-tube boilers.

The proposal made in his paper for short fires and very limited rate of combustion, must entail very much space devoted to the boilers. If this is at the expense of the room for the stokers, they will suffer the more from heat. At the same time the quality of coal available has much to do with the rate of combustion that can be maintained, and by the use of powerful fans the temperature of the stokeholds can be much reduced.

In order to save the crew from fatigue in a war ship, as far as possible, water-tube boilers are a necessity, I believe; but for this purpose they must be adapted to stand strong forced draft, so as to raise steam very quickly. Their weight, together with that of the coal they will burn in a certain time (depending on the proposed service), must be as small as possible, so as to give the best speed to the ship and reduce the work of the crew.

The necessity for internal cleaning of the generating tubes has not been proved for all kinds of water-tube boilers, I think; and as curved tubes afford means of withstanding rapid, irregular heating, and also allow a better separation of steam from the water in the boiler, I consider they are best for the purpose of steam supply in war vessels.

A. F. Yarrow.—The only reason why, I apprehend, curved tubes were and still are adopted by many makers of water-tube

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boilers is that an engineer naturally and properly deems it necessary to make ample allowance for various rates of contraction and expansion in different parts of the same structure. Experience, however, indicates that in water-tube boilers having good circulation the elasticity of the tubes is sufficient to make the necessary allowance, and, as far as our experience goes, we have no reason whatever to regret having adopted straight tubes from the beginning.

I think Mr. Robison has done right in drawing attention to the necessity of greater uniformity of design in marine engine construction, and one cannot help remarking that in almost all the navies of the world one sees vessels of the same class and in large numbers with quite needless differences. I refer now more to torpedo boats, torpedo-boat destroyers, and such like, where, certainly, a great gain, in time of war, would be found if the spare parts suitable for one boat were available also for others.

I am quite aware that any one occupying a responsible government position cannot do what a private individual can, namely, give decided preferences freely to special firms and to special designs. I also am quite aware that it would be a very dangerous thing to tie the hands of contractors too closely by regulations which might affect efficiency of design, as this would, if carried too far, retard progress. Nevertheless, I do think a great deal might be done, certainly more than at present. For example, in vessels of the same class one meets with condensers two inches larger in diameter and four inches shorter in one vessel than in another, both of the same cooling surface. Surely there can be no charm or gain in any such differences, but if they were both alike, the same spare condenser tubes would come in. This is one of the many examples which can be quoted where a certain amount of uniformity might be adopted without possible objection and with undoubted gain; and in time of war it would certainly be a source of great convenience for the spare gear of one vessel to be adaptable to suit another vessel. I think, therefore, Mr. Robison has done a public good in drawing attention to what has hitherto been greatly disregarded.

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Jules D'Allest.—Mr. Robison's article on the technical lessons to be drawn from the Spanish-American war, from the point of view of the marine engineers, is very interesting, and I do not doubt that his very judicious conclusions will be widely noted. It is with pleasure that I give my opinion on this work, as it expresses my ideas in all points as regards boilers.

The difficulty in obtaining trained firemen is encountered not only on men-of-war in time of war, but also even on merchant vessels in times of peace. Taking this into consideration, it is evident that when a large number of vessels are to be put into commission at one time, those that have the least complicated boilers will be able to make the longest cruise.

It is to be remarked that from the beginning of the war difficulty was experienced in obtaining fresh feed water for the boilers; that the tubes were rapidly fouled on both the water and the fire side; that the grates became dirty; that it was with difficulty that more than 25 pounds of coal were burned per square foot of grate surface per hour, and, finally, that it was of the greatest value to be able quickly to obtain steam.

It seems a logical conclusion from these conditions, that for military purposes water-tube boilers are the best, provided, of course, that they must be easily worked and easily cleaned. The working will be easy if the boiler contains sufficient water to render the maintenance of a proper water level no more complicated than with ordinary boilers. The easy working will be equally aided if complete combustion can be secured even with bad firing. Mr. Robison is right when he says that this is a difficult requirement to satisfy; but while not wishing to unduly praise our own boilers, I must state that this is the end which we have always sought, and which we have attained. For this purpose we have coupled our boilers in pairs, as is well known, with a common combustion chamber, and we have forced the firemen on our ships to fire alternately these two boilers, and never to fire them together. In this way, if one of the fires is too heavy, the other is, on the contrary, at the same moment, not heavy enough. The gases from the heavy fire are burned *in the common combustion chamber* by the air arriving in excess by way of the light fire.

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We have also succeeded in obtaining in practice and over very long distances a high rate of combustion that was very economical by using what is called methodical firing, something that has been well-known but very seldom used except on trials. Thus, if, say, 20 pounds of coal are to be burned per square foot of grate surface per hour, the total weight for a furnace for a given time is divided into several small charges of say 50 pounds each, which are used at regular intervals varying from five to ten minutes. If briquettes are used the number of briquettes to be used is known in advance. Every five minutes an electric bell sounds automatically in the fire rooms. At this signal, for example, the even-numbered furnaces are fired, while at the following signal the odd-numbered furnaces are fired. By this simple means it is readily seen that we burn under the most excellent economical conditions much more coal per square foot of grate surface per hour than could be done by leaving the firemen free to fire the boilers in their own way.

It seems to me correct that straight tubes, with the interior accessible from each end, are the best. They can be readily cleaned, and a clean boiler produces steam freely and is less liable to accident. It seems also correct that these tubes should not be too small. In that case cleaning would be impossible, and they would be quickly choked by scale. It is evident now that on cruising men-of-war sufficient fresh water can be obtained only with great difficulty, and from this point of view boilers capable of using, if not pure sea water for feed water, at least salty water, must be very highly desirable.

Mr. Robison is quite correct in what he has said concerning the maximum allowable rate of combustion. A war vessel should have sufficiently powerful boilers to obtain the extreme trial speed without burning over about 25 pounds of coal per square foot of grate per hour; this because during any prolonged period at sea the forced-draft system may get out of order, and because it may be necessary to use coal of such a quality as will render impossible a high rate of combustion without rapidly destroying the grates.

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John Platt.—The importance of the matter of *uniformity* in the spare parts and stores for different ships cannot be overestimated. But there are other things which make absolute uniformity, even in such desirable things as grate bars and boiler tubes, an uneconomical desirability. In speaking of boiler economy, later on, this subject will again be referred to.

The great increase in the materiel of the navy in time of war, and the fact that inexperienced men have to be employed in the working of the boilers, has an important bearing on the type of water-tube boiler to be employed. The boiler must not be of such a design and construction that a small departure from the proper method of working will affect it to such an extent that a great reduction in economy, and perhaps disaster, will be the result. That certain boilers are open to this objection has been shown by the working of the water-tube boilers on some of the biggest ships in the British Navy, even with the regular service engineers and firemen, the greatest care and the assistance of the boiler people themselves, low economy and trouble have existed. It has been pointed out that the fire room is perhaps more seriously affected by war conditions than any other part of the ship; hence more serious trouble may be looked for when the service-trained men are not attainable.

The small tube water-tube boiler, from its construction, is of necessity the one which will best serve the requirements set forth that it must be possible to obtain full boiler power on short notice.

Great stress was laid by Mr. Robison on the coal question, and of the necessity of economizing the same. To get full power with the cylindrical boiler at short notice it was necessary to have all fires in proper condition and to be constantly using coal. With the boiler with small curved tubes—even if the boilers were cold—with fires laid, full steam pressure would be obtained in from fifteen to twenty minutes.

In installing water-tube boilers in big ships provision will be made for the ready cleaning of the outside of the tubes. This can best be done by having compressed-air pipes run along the fire rooms, so that a hose can be coupled and all soot and dirt

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blown out. This is a marked improvement over the steam jets usually employed, and was suggested to the writer by Chief Engineer Freeman, who used it on the *Nashville* with great success.

Scale on the inside of the tubes has been urged against the use of the boilers with small bent tubes. The best thing to do is to refer to past experience to show that in such a boiler, properly designed, where the tubes discharge into the upper drum above the water level, the circulation is so rapid that all deposit is carried through the small tubes and eventually settles in the lower drum, from which it is readily blown off.

We can refer to the boilers of the U. S. torpedo boat *Ericsson* as an excellent example. These boilers were in use between four and five years, they never received any special care, and whilst in use before Santiago were repeatedly salted, from conditions over which the officers in charge had no control. Notwithstanding all this, it was found on taking some tubes from the boiler and cutting them up that they were in thoroughly good condition and free from dirt and scale.

The action of dirt in the water when used in "light tubulous boilers" in torpedo boats is spoken of as having caused severe priming at high speeds. This class of priming is not caused in the case of the small-tube boilers where the tubes are above the water level in the top drums. The tubes being designed to carry over steam and water, the water being carried down to natural water level by the separator, and the steam escaping to the steam space, renders this boiler free from the very serious defect of carrying over water with the steam which is delivered into the main steam pipe, even under the most unfavorable conditions.

Stress is laid upon the fact that under conditions of war, through dirty fires, etc., the combustion of coal per square foot of grate was abnormally low. This being the case, it is advisable to have a boiler of such a design that a comparatively high degree of forcing can be resorted to, so that even with the fires in bad condition, as large an amount of coal as possible can be burned. As the burning of only twenty-five pounds of coal per square foot of grate leads to the use of a larger boiler than necessary for naval

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work, means should undoubtedly be taken to make it possible to obtain better results. It is possible to design a boiler that is highly economical (for big ship conditions) under a high degree of forcing. A high air pressure can be procured, and with this the greater part of the dirt is blown into the stack and the fires kept in a much better state. In English destroyer practice they run the three-hours' trials, burning between sixty and seventy pounds of coal per square foot of grate, without cleaning fires, and at the end of the trial the fires are in good condition, and there is but little refuse in the ash pans.

In considering what is required to properly meet war conditions, stress is laid upon uniformity of design. This is undoubtedly, as before mentioned, a very important factor, but in the main steam plant it must not be allowed to unduly influence economical working conditions. The main reason why the length of the grate cannot always be the same, is the fact that sometimes from the nature of the general design of the vessel the boiler space available is such that to get in the largest possible amount of grate area a difference in length is necessary. The grate should be as short as possible, and should, under no circumstances, be over seven feet in length; it is only the great height of the fire box in certain water-tube boilers which makes it possible to properly fire this length.

Exception must be taken to the possibility of obtaining a constant length of boiler tubes. It is not possible to build an *economical* boiler for ships of different types, to meet the very different service conditions demanded, and at the same time to keep a fixed length of tube. A large grate area is desirable, but for a given power too large an one is not to be recommended. A small fire, properly worked, can be made to give better results than a large one. Because a very large grate area is necessary in some types of boiler on account of the boiler being in itself uneconomical, the same large area should not be demanded in a more economical type in which the coal can be burned to better advantage. The burning of only 25 pounds of coal per square foot of grate, on contract trials, which are made under most favorable conditions, is open to objections, and can be made

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to work against the best interest of the boiler plant. If very valuable room in the ship is taken to put in a larger boiler plant than is necessary for a given power, and the power obtained on the trial with this low rate of combustion, it is quite possible under such conditions to use a type of boiler that under adverse war conditions will not develop the required amount of power. As a boiler of high efficiency at high rates of steaming can be obtained, the economical burning of a much larger amount of coal per square foot of grate should be insisted upon at the start.

If the above conditions are fulfilled, it will also follow that the boiler will be capable of raising steam from cold water in the shortest possible space of time.

There need be no fear that a battery of water-tube boilers will not be divided into small enough units. The fear is that the units will be too small. The disadvantage of two small units is that this means a large number of extra fittings valves, and connections to the main steam pipe. But a more serious objection still is the increased number of water levels that have to be taken care of. The smallest number of water levels possible, considerate with the economical overhauling of the boilers, should be insisted upon. For a battery of 18,000 horse power for naval service the writer would suggest twelve units; each unit having one main steam drum and two entirely separate fire-grate chambers, the grates being about 6 feet 9 inches long.

Boilers should undoubtedly be accessible to repairs and cleaning, but it is even more desirable to have a design in which repairs are reduced to a minimum. Most of the repairs are rendered necessary by unequal expansion and contraction in the boiler, due to the sudden raising of steam and rapid temperature changes. Under the circumstances repairs will be the least where this expansion is taken care of, as it so successfully is in the class of boilers with small curved tubes, the tubes entering the top drum above the water level.

The ideal boiler sought after will, we think, have to be capable of sustaining a high forced draft economically. First, so that as large an amount of coal as possible per square foot of grate

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can be properly burned, not that under trial conditions a larger amount than 25 pounds per square foot is necessarily desirable. Secondly, from constructive reasons the boiler that will meet these forced conditions will be the most economical possible under ordinary rates of steaming.

It is the fact that the "comparatively direct and unobstructed course of the gases of combustion renders them uneconomical with high forced draft," which has made possible the many serious objections raised against water-tube boilers on account of lack of economy.

Boiler-room space can only be brought down to that taken up by the old type of boiler by the use of a boiler that is capable of economical forcing. It will be noted that in all cases the writer couples economy with the forcing.

The number of attachments can best be kept small, and the boiler room work rendered reasonably easy by the use of a boiler which does not from structural reasons render a very large number of units a necessity.

The complete combustion of the fuel can be obtained where too great a width and length of grate is not in question, provided the combustion chamber is very large, and the passage of the gases properly guided by walls of tubes through a large space into which they can expand before reaching the uptake. A high combustion chamber renders the use of an observation window possible, and with this it is very easy to prevent holes in the fire.

The water levels can be kept steady by the use of feed-water regulators, but, as before stated, the fewer the number of levels to be looked after the better. In big ship boilers there is no difficulty in making the top drum large, and thus provide a large area of cross section at the water level.

The plugging of small tubes is such an expeditious and easy matter, and with a good design of curved-tube boiler the repairs to the tubes so small, that the writer can not at all agree with the view that the straight-tube boilers can be more readily repaired. The cases of the *Cushing* and *Ericsson* can be cited. After four and five years' service it was found that only seven

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or eight tubes had been plugged, none at all having been replaced.

The paper by Mr. W. R. Cummins in the November JOURNAL on "High Pressure at Sea" gives a good idea of the different types of water-tube boilers, and the writer generally agrees with his deductions. In writing of the Thornycroft boiler he is unfortunately guided entirely by the design of those used in torpedo-boat practice; for the big ship service important improvements are possible. On page 1079 he states that "the passage traveled by the gases before they reach the uptake is only a little over five feet." This leads him, in his deductions on page 1082, to state that the boiler, although it burns the fuel better, it does not utilize the heat as well as those of the large straight-tube type. In the new design the gases have to travel from ten to twelve feet, a great enough distance to make them utilize the heat as well as any of the boilers he names. The design also allows for a much larger amount of water, and hence the difficulties owing to irregularities of feed are done away with. This new and improved design, therefore, does away with the only two objections he was able to raise to the class to which it belongs. There is a further advantage, which was not touched upon, and that is the great reduction in weight made possible by their use. Here the reduction is enough to make it of real moment. In the case of some of the boilers of the straight, large-tube variety the reduction in weight is so slight that the same advantage does not exist.

The successful installation and operation of over 600,000 horse power of water-tube boilers for marine service by one firm can surely class this as more than an experiment, particularly as very many of them are used under the most trying conditions of boiler service, with the extremest possible driving, and with high economy. Surely if this has been the case, under the easier and more satisfactory conditions of big-ship service they will continue to be as successful as in the past. This success has also been attained without the aid of either the "feed heaters, air heaters, and all sorts of economizers" referred to by Mr. Robison.

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Change in conditions has made improvements in detail and even in general design possible, and further experience will always, as in the past, make it possible to still further work up towards the high ideal sought after by Mr. Robison in his very able treatise on the subject.

W. D. Hoxie.—Mr. Robison does not refer to the use of water-tube boilers in the merchant marine, but all that he says regarding their advantages for ships of war holds good for ships of the carrying trade.

It was a stubborn fight the early builders of stationary water-tube boilers had, when it was thought by most purchasers that the only boilers that could be depended upon to make steam continuously were the cylinder, two-flue or the return-tubular type. It is a little remarkable that the industry in which water-tube boilers were most extensively used was the manufacture of sugar, for, of all stationary power plants, the sugar house comes nearest to a transatlantic liner. A sugar refinery runs night and day, the demands on the boilers are continuous and severe, and during the period of boiling sugar in vacuum pans the boilers are operated under a strong forced draft. Since the early seventies this type of boiler has been used for nearly all kinds of manufacturing, and in later years has played a most important part in the generation of electricity. To-day there is hardly a large electric-light or power plant constructed but water-tube boilers are installed. At the last electrical exhibition held in New York City, it was shown by one concern building water-tube boilers that they had in successful operation enough boilers in use in the generation of electricity to supply a chain of 16-c.p. incandescent lamps, twelve feet apart, that would reach around the world.

Every year adds many converts to the already long list of ship owners using water-tube boilers, and there is no better proof of their entire satisfaction than is evidenced by the increasing number of new vessels having them installed and the frequent replacement of cylindrical boilers with those of the water-tube type. Especially is this true on the Great Lakes of North

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America, where competition is exceedingly active, and where a ton of freight is carried cheaper than on any other body of water in the world. Space and weight are saved for the same horse power developed, a higher steam pressure is carried with safety, the steam consumption of the engine is thereby materially reduced and greater economy obtained.

If properly constructed, of *straight* tubes that can be purchased in the market, with tube ends that are accessible, the cleaning of the boilers, both inside and out, may be thoroughly and quickly performed. Generally, such a boiler can be repaired by the ship's staff without calling for the assistance of boiler makers and the use of shop tools. A few new tubes and the water-tube boiler is as good as new; there are no furnaces, crown sheets or combustion-chamber plates to drop and bulge, from whatever cause.

After the recent war with Spain, it was found necessary to renew the furnaces of the battle ship *Indiana*, requiring the services of not only the New York yard, with its gang of boiler makers, but the furnaces had to be corrugated in a particular shop; all this detained the ship at the yard for four months. Had the *Indiana* been equipped with say ten water-tube boilers of the straight-tube type, the tubes being expanded into place with ends accessible, the first three rows over the fire might have been removed and replaced, whether blistered, burned or bent from salt and oil in the feed or from any other cause, and repairs made entirely by the ship's talent in not more than three weeks' time.

One of the largest firms shipping ore from Lake Superior equipped a year ago a new 6,000-ton freighter, with water-tube boilers, and when asked what they considered one of the greatest advantages attained by the use of these boilers, replied: "We can load our vessels at the rate of a thousand tons an hour and unload them almost as quickly. This means that our stay in port is only a little over six hours. In that time we can blow a boiler down, make a joint on boiler, steam piping, grind in a leaky safety valve or renew a tube, can refill and have full steam and be ready to sail for destination as soon as the ship is loaded,

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and yet have no fear of straining the boilers from unequal expansion in getting steam quickly. With our old cylindrical boilers we would just about have them cooled off ready to work upon by the time the ship was loaded and the rest of the time placed upon the repairs, refilling, and slowly raising steam, means detention of the ship and loss to us."

Mr. Robison makes a statement as to the design of a water-tube boiler, but does not refer to materials of construction. There should be no more cast iron, malleable cast iron, or cast steel used in the pressure parts of a water-tube boiler than is now allowed in the construction of a cylindrical boiler, which is *nil.* This is especially important where high-pressure steam is carried. Any of the cast metals placed under pressure are unreliable, even those that are so called annealed, which process of annealing means the burning out of the carbon in the casting, leaving small holes which render the casting porous. The difficulty in obtaining sound steel castings is so well known that their use for pressure parts of boilers is exceedingly unwise, if not positively dangerous.

The water-tube boiler that is to stay in service should therefore be constructed of open-hearth forged steel and drawn tubes, with only cast metal in use for grate bars. The most serious repairs would then consist of a new set of tubes, for tube-end connections made of forged steel cannot crack, even if the boiler were neglected and badly burned.

There is a prevailing opinion among some designers that all water-tube boilers must be constructed of material representing a minimum of weight for a maximum of heating surface. Such boilers have a service to perform, and a good one, namely, in the torpedo boat or destroyer, where the weight of boiler with water per square foot of heating surface should not exceed twelve or thirteen pounds; but no water-tube boilers built on these lines has ever been used in the merchant marine, and it is very doubtful if they will meet with lasting favor in the larger vessels of the navies, as their tubes and casings are so very light that they suffer greatly from interior and exterior corrosion, which soon renders their sea service questionable.

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The pendulum of opinion as to weights is swinging to its limit. It must return, and when it does, will finally come to rest at the water-tube boiler, whose weight is about midway between the heavy cylindrical boiler and those of the express type. Such a boiler can go to sea without fear of breakdowns, and when called upon to steam continuously on long voyages, will be found to contain sufficient metal to perform all the duties now required of the cylindrical boiler, and possess advantages already enumerated, that will cause it to outstrip its old rival in the race for supremacy.

George W. Melville, Engineer-in-Chief, U. S. Navy.—While appreciating the many good points in Mr. Robison's article, I am sorry to say that my first impression on reading it was a disappointment. I have learned to appreciate Mr. Robison's ability very highly, and the array of facts which he presents is disappointing simply because, it seems to me, he has not made the most of his case. I know exactly why this is so, and am glad of the opportunity to state, for the benefit of those who may not understand the reason, that Mr. Robison's duties as one of my assistants for some months past, have kept him so very busy that it was simply out of the question for him to give the time and attention necessary to present his paper in the finished form in which it would undoubtedly have appeared had the circumstances been different.

With regard to the matter of an ample supply of fresh water for the boilers, I think it is pretty well understood, by those familiar with the service, why it was that the trouble arose. We had not had the opportunity before the war broke out to prepare the distilling ships, which we began as soon as funds were available. The *Iris* was finished in time to go to Montauk Point to supply pure drinking water to the army, and it may not be amiss for me to call attention to the fact that on test her capacity of drinking water which would stand the nitrate of silver test, was found to be 75,000 gallons per diem, while of water fit for boiler feed she made over 100,000 gallons per diem.

The advantages of a distilling ship, rather than a tank steamer,

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for supplying water to a fleet, are very obvious. The distilling ship has a very economical triple-effect evaporating apparatus capable of supplying over twenty tons of water for each ton of coal burned in the boilers. As a consequence, if the bunker capacity is 3,000 tons, it gives us a potential water supply of 60,000 tons, while even a large tank steamer would not have a capacity of more than 5,000 or 6,000 tons. In addition, with a distilling ship, we can supply absolutely pure drinking water for large bodies of men, while the "tanker" must take the water at the nearest source of supply and trust to luck for its being fit for drinking purposes, if that should be desirable.

I may say in connection with this matter of water supply, that we are increasing the evaporating plant of all our ships where there is sufficient room, by installing additional evaporators, so that even without the distilling vessels, there will be less trouble in the future.

I think Mr. Robison's dictum, under No. 6, on page 1003, that "not more than about twenty-five pounds of coal per square foot of grate can be burned for any length of time," is too dogmatic an assertion, and hardly consistent with facts. The rate of combustion in the transatlantic liners, nearly all of which now use forced draft, is considerably higher than this. The amount that can be burned does depend, in the last analysis, on the skill of the firemen and their ability to keep the fires properly cleaned. Mr. Robison's point is made, of course, with the idea of providing such an ample grate surface that inexperienced firemen will still be able to get adequate power from the machinery.

I cordially indorse his remarks on the subject of uniformity in designs, for it is what I have been urging in my annual reports for some years past. The advantages of uniformity appeal to every one connected with the Navy, as shown by the remarks of Captain Mahan in McClure's Magazine for January, where he commented on the great advantages of having all the units in a fleet absolutely alike. This holds just as much with regard to the machinery as to the hulls or the guns.

Mr. Robison makes a good point with regard to the desirability of having the boiler power in small units, as enabling them

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to be laid off one at a time for cleaning or repair without materially reducing the aggregate boiler power; but obviously there is a good deal to be said on the other side, both with regard to the first cost of the increased number of fittings, the increased weight and the difficulty of maintenance where there are so many small units. I am certainly not prepared to indorse his statement in the form he has put it. I should rather have been inclined to state the proposition as recommending the desirability of increasing the number of units as far as practicable without sacrificing other considerations, in order to provide for cleaning and repair.

The conclusion which Mr. Robison reaches finally, that water-tube boilers are tactical necessities, of course has my hearty indorsement. If the battle of Santiago taught nothing else, it certainly made very clear the absolute necessity of water-tube boilers for our modern war vessels.

With regard to the type of water-tube boiler, so much has been said that it hardly seems worth while to discuss the matter again. My own personal preference is for boilers with straight tubes, yet at the same time, it cannot be questioned that the small-tube boilers also have many good points and have some advantages over the boilers with straight tubes. I have no doubt that as time passes and the different varieties of water-tube boilers are thoroughly tested in every-day service, we shall finally discover one or more forms of water-tube boiler which are on the whole most satisfactory, and then they will become the standards. Mr. Robison has made the subject of water-tube boilers a very careful study, and anything he says on the subject is sure to merit careful attention.

J. K. Robison.—I heartily thank the gentlemen who have so kindly dealt with my remarks and who have added so greatly to the value of the paper by their discussion of it. Our Engineer-in-Chief says: "If the battle of Santiago taught nothing else, it certainly made very clear the absolute necessity of water-tube boilers for our modern war vessels." Here is settled the great question of water-tube boilers, at least as far as our Navy

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is concerned. The details are less important and will soon work themselves out satisfactorily.

In regard to the maximum rate of consumption allowable on war vessels on the trials, I must say that I consider "thirty to thirty-five pounds" per square foot of grate surface per hour none too low. It is to be noted that in this war we had the best coal in any market, and that we had quite as good firemen as we are likely ever to obtain during a war, yet we seldom, if ever, after having been under way for any considerable length of time, were able to burn over thirty pounds of coal per square foot of grate.

On one occasion, at least, this is the best that could be done with four inches of air pressure in the fire room, and this on a ship—the *Oregon*—that burned somewhat more than this figure on the trials with an average of but one inch air pressure. It seems to me that to adopt this dogma would be simply to carry into effect the knowledge derived from our war experience, and that it would simply extend to all war ships the rule we have had for many years, limiting the forced draft on our battle ships. I think there are few Atlantic liners that burn regularly over thirty-five pounds per square foot of grate surface per hour, and it is to be remembered that on these ships forced draft conditions are the normal ones.

In regard to the matter of spare boiler and condenser tubes, it may be worth while to say that we carry the longest tubes of each diameter as a stock of spares. In an emergency it has often been found best to waste a few inches from the end of the tubes and thus secure a tube fitted to a short boiler or condenser.

I feel bound to state that while I am sure that a boiler that will perfectly meet naval demands and conditions must have straight tubes, it is not by any means clear to me that among present designs the straight-tube boilers are the best for all purposes. Freedom of expansion and the quick raising of steam are necessary as well as accessibility for cleaning. There are patent advantages and disadvantages for each type. This subject has been very thoroughly discussed already.

The desire not to be wearying must be my excuse for not having done more than indicate lines of reasoning that I am sure all engineers follow.

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THE PRODUCTION OF METALLIC TUBES BY EXTRUSION.

[Reprinted from "Engineering."]

At the spring meeting of the Iron and Steel Institute in 1896, a paper was read by Mr. Perry F. Nursey describing the process of, and the machinery for, manufacturing metallic bars of any section by extrusion at high temperatures. This system is the invention of Mr. Alexander Dick, and by it all kinds of metallic sections are produced, from a simple round wire to complex designs with re-entering angles, which it would be impossible to roll, by forcing metal, heated to plasticity, through a die under hydraulic pressure. These sections are all solid, but since the reading of that paper, which was published by us at the time, Mr. Dick has made the important discovery that copper and its alloys in a heated and plastic condition can be separated, and, provided no air has access to it to oxidize the fresh surfaces, they will reunite by simple pressure. A true weld is thus formed which it has been found impossible to rupture. Upon this discovery Mr. Dick has founded and perfected a system of producing metallic tubes of any section by the same process, and their manufacture is now being carried on concurrently with that of the solid sections. Of course we do not overlook the fact that the principle of extrusion has been applied in the production of leaden pipes and leaden rod for the manufacture of projectiles for small arms. But, in those cases, the lead is pressed at a comparatively low temperature, whilst in the present instance the metal has to be operated upon at a very high temperature, namely, that of plasticity, or about 1000 degrees Fahrenheit.

The process of manufacture is carried on by means of a press. The machine is 16 feet in length, 6 feet wide, and 5 feet high over all. It consists mainly of the compressing cylinder or container,

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and the hydraulic ram. The heated metal is placed in the cylinder, at one end of which is the die, and upon pressure being applied at the opposite end the plastic metal is forced through the die issuing therefrom as rods, or as tubes, of the required section and of a length governed by the quantity of metal placed in the container. This container has not only to withstand the high temperature of the metal, but it has also, whilst under the influence of that temperature, to meet the severe strain brought upon the interior by the resistance of the metal to the pressure of the hydraulic ram in forcing it out through the contracted area of the die. The construction of the container was, therefore, an anxious matter, and the designing of it gave some trouble, but at length all difficulties were overcome and every working requirement amply met. The container, which is 2 feet long and 2 feet in diameter externally, has an inner liner of cast steel. The internal diameter of the liner varies in different containers from 5 inches to 8 inches, according as to whether it is wanted for pressing a small or a large charge, the container being changed as required. The liner is enclosed within a series of cylinders of ordinary mild steel spaced about ¾ inch apart, the annular spaces being filled in with a non-conducting material composed of crushed granite mixed with a small proportion of borax. The container is mounted on trunnions and fitted with worm gearing for bringing it to a vertical position for being charged with metal and restoring it to the horizontal for the operation of pressing.

The die plates are made of tungsten steel, and they are formed with either one or several openings, each opening being, in the case of rods and bars, of the section required to be given to the article produced. In the case of tubes there is a mandrel in the center of the opening in the die plate. This form of die is shown in Figs. 2 and 3, Fig. 2 being a vertical section and Fig. 3 a plan view at the back of the die, or that portion which presents itself to the incoming metal in the operation of pressing. Upon the plastic metal meeting the sharp edges of the ribs or wings of the die, the stream becomes divided, and is conducted in several streams to the mandrel, around which the incoming metal is pressed. Here the divided streams of metal are re-united as a

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tube, and become firmly welded together, so that it is impossible to discover the points of junction in the finished tube. This re-union is dependent upon the exclusion of the air, which would otherwise cause oxidation of the surfaces of the metal, and prevent them uniting. A singular verification of this is shown by the fact that for a few inches at the front end of every tube the metal is never united, as will be seen from Fig. 1. It might be thought that this was due to the cooling action of the die on the metal. This, however, is not the case, inasmuch as at the commencement of every run the die is heated to a cherry red, the initial severance being solely due to the presence of air in the die, and the subsequent re-union of the metal, to its absence.

The die-plate is mounted in a holder, in which it is easily fixed, or from which it is readily removed, as different sections are required to be pressed. As it is necessary to heat the die and its holder previously to each pressing operation, as already mentioned, the die is fitted into a shouldered recess in the holder, which is coned to seat into a hollow metal block. This block is firmly held in position during the operation of pressing by a pair of gripping jaws actuated by hydraulic power. The die holder and the gripping jaws are carried in a strong crosshead. The metal is forced out of the container and through the die by an hydraulic ram 20 inches in diameter, and working under a pressure of two tons per square inch. The ram has a prolongation or extension of reduced diameter, which forms the plunger of the container, entering it at the opposite end to that at which the die is situated. A different plunger is used with each container, the diameter varying to suit the internal diameter of the container. On starting to work each day the container is first heated up by gas with a Bunsen burner, which quickly brings the liner to the temperature necessary to prevent the first charge of metal receiving a chill. The container does not require reheating, as the liner remains red hot after each run.

Such in general is the arrangement of this ingenious system of tube production. Its operation may be best described from our own observation during a recent visit to the Delta Metal Works, Pomeroy street, New Cross, London. The machine was

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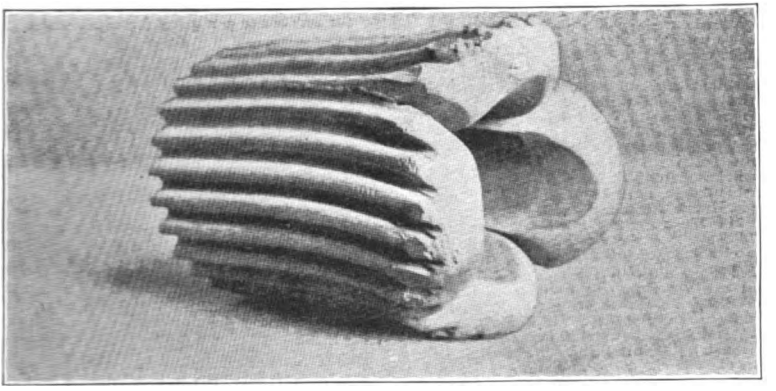

FIG. 1.

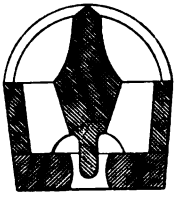

FIG. 2.

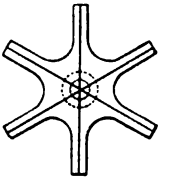

FIG. 3.

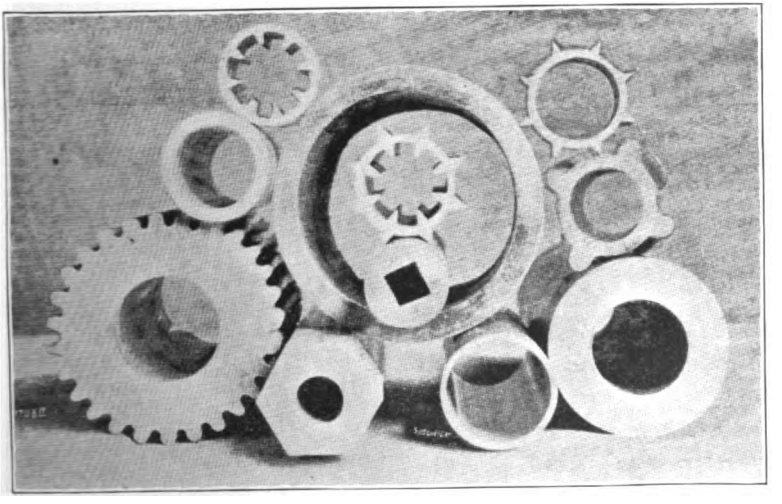

FIG. 4.

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running on tubes of 2½ inches and ¾ inch in diameter respectively. In the case of the smaller tubes, four were produced at each pressing, whilst in the case of the larger tubes only one was produced at each run. A charge having just been put through, the opening at the front end of the container—that next the die—was closed by a removable plate or stopper, and the container was up-ended in a vertical position with the closed end at the bottom. A billet of delta metal weighing about 1½ cwt. and heated to plasticity was then placed in the container. The diameter of the plunger, and that of a loose block which is placed between it and the charge, being less than the diameter of the steel liner, the plastic material when under pressure would be forced backwards between the block and the liner were it not restrained. In order to prevent this back flow taking place, a dished steel check disc which is less plastic and more rigid than the heated metal at the working temperature, is first placed on top of the charge, and when the pressure is brought on the disc is expanded and completely fills the bore of the liner, thus effectually preventing the back flow of the metal.

The loose steel block just referred to was then placed upon the check disc, and having been previously heated, it prevents the cold end of the plunger chilling the charge of metal. The plunger being of smaller diameter than the liner, there is no fear of the latter becoming chilled by the former. To preclude all chance of such an occurrence, however, the back of the loose block is recessed and receives a corresponding projection on the front end of the plunger, which is thus maintained in a central position and is prevented from coming into contact with the liner. The block having been inserted, the container was brought into a horizontal position, the front stop plate removed, and the container run up to the die block which, with the die, had been previously heated. The hydraulic pumps were then started, and in four minutes the charge was expelled and had become connected into lengths of tubes of the diameters stated. The gripping jaws were then released and the ram continued its forward travel, pushing out the remainder of the metal or stump, together with the die and its holder as well as the check disc and the loose block,

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leaving the container perfectly clear for the next charge. The tubes were then cut off from the stump or fag end of the charge; the die and holder replaced by others; the stopper of the container fixed in place, and the container up-ended for another charge, a similar cycle of operations to those just described being then carried out.

We thus have an ingenious application of the principle of extrusion to an important industrial purpose. That the system possesses great possibilities is evident from the variety of tube sections that are produced by it in delta metal—which itself embodies several important physical characteristics. The wide range of tube sections produced will be seen on reference to Fig. 4, which illustration is prepared from a photograph of some of the sections ordinarily being made. The process, moreover, improves the quality of the metal owing to the great pressure put upon it, in the same way that Whitworth steel is improved by compression. Some tests made at Woolwich Arsenal with delta metal bars produced by extrusion, show a tensile strength of 48 tons per square inch, with 32.5 per cent. elongation in 2 inches, against 38 tons per square inch tensile strength and 20 per cent. elongation of rolled bars of the same metal. Compared with ordinary yellow metal the increase in tensile strength is 24 per cent., with a proportionate increase in elongation. In some tests made in France with rolled yellow metal bars, the tensile strength was 50.5 kilogrammes per square millimeter, with 18 per cent. elongation in 10 centimeters; whilst extruded bars of the same metal gave 54.6 kilogrammes per square millimeter, with 25 per cent. elongation in 10 centimeters. Rolled delta metal bars gave 73.3 kilogrammes per square millimeter, with 28.8 per cent. elongation in the same length; whilst extruded bars of that metal gave 76.6 kilogrammes per square millimeter (48.6 tons per square inch), with 29.8 per cent. elongation.

That the extrusion process considerably increases the strength of tubes is shown by some tests, in which the mean bursting pressure of three samples of extruded brass tubes 1.236 inches in diameter by 0.073 inch thick, was 6,570 pounds per square inch, which, by the well known formula

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$$p = \frac{D^2 - d^2}{D^2 + d^2} f,$$

in which

p = bursting pressure in pounds per square inch,
D = outside diameter in inches,
d = inside diameter in inches,

gives a value of 54,000 to f for extruded brass tubes, whereas in ordinary solid-drawn brass tubes the value of the constant f is only 30,000, and even for manganese-bronze tubes only reaches 44,500. With regard to tensile strength, pieces of extruded brass tubes were tested longitudinally and transversely, the mean of six tests of the former giving an ultimate strength of 31.5 tons per square inch and 29.3 per cent. elongation, the six transverse specimens giving a mean of 28.8 tons per square inch with 9.8 per cent. elongation.

The development of the extrusion system of manufacturing metallic bars and tubes is shown by the circumstance that there are no fewer than nineteen presses on Mr. Dick's principle in operation in this country and on the Continent, whilst plant for three more is being laid down. The presses already in operation are at present turning out solid sections only, but they are all being fitted with the necessary appliances for the production of tubes by extrusion.

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INDICATOR DIAGRAMS OF MULTIPLE-EXPANSION ENGINES.

By B. C. Ball, Member.

A few years ago the writer worked up a system for drawing indicator diagrams for multiple-expansion engines which he believes to be original in some respects, and which has some points of advantage over any other system with which he is familiar. Mention was made of it in a paper presented by the writer's father, Mr. F. H. Ball, to the American Society Mechanical Engineers, vol. xv., page 771.

Almost all the methods in general use for constructing theoretic indicator diagrams disregard the fact that the amount of compression of steam into the clearance spaces has an important effect upon the relation between the diagrams from the different cylinders, as well as upon the economy of the engine. It is generally assumed that the compression will fill the clearance spaces, and no further attention is given to that part of the diagram. In actual practice this is very seldom the case, and tests have been made which show that, for the sake of economy, compression should not fill the clearance space. Prof. D. S. Jacobus conducted one such test, and reported the results to the American Society Mechanical Engineers in a paper, vol. xv, page 915. But the object of this paper is not to discuss the question of what the compression should be, and this was only referred to, to show that it is not due to a faulty engine that the compression does not fill the clearance spaces.

The effect of varying compression in engines having moderately large clearance becomes very important if we want to know accurately what results can be obtained under certain conditions. For instance, it is possible to increase, to a considerable extent, the I.H.P. of a compound engine by simply making

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the high-pressure valve close later for compression, without changing any other condition. So to get accurate results we must take the compression into account; and this is true, not only in drawing diagrams, but in combining them also.

In constructing the following diagrams no allowance will be made for the many deviations from a perfect diagram, such as wire-drawing of steam through ports, &c., for such deviations are very different in different styles of engines; and as these diagrams will be used to illustrate two different methods of combining diagrams, they will show more clearly the points to which I desire to call attention, if there are no losses except those due to free expansion into the clearance spaces at admission and into the receiver at release. The losses due to wire-drawing, rounding of corners, &c., must be determined for each particular case, when the peculiarities of the engine under consideration are known.

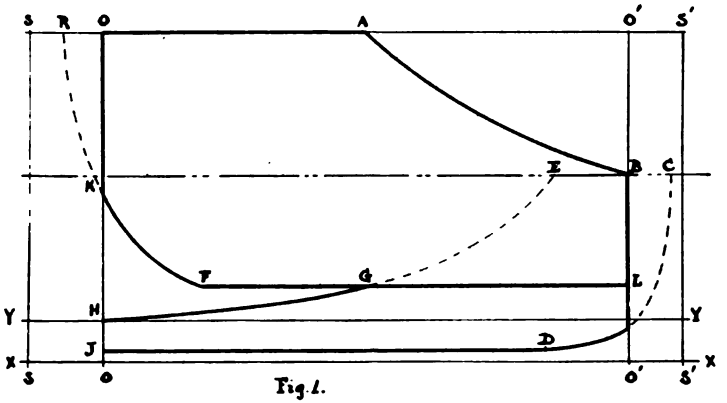

Fig. 1.

Fig. 1 shows the construction of diagrams for a compound engine, the following data being assumed: initial pressure, 120 pounds, absolute; vacuum, 11 pounds per square inch in the cylinder; ratio of expansion, 8; clearance in cylinders, 15 per cent. in the high pressure, and 10 per cent. in the low pressure; cut-off 0.5 in both cylinders; valve diagrams known. The expansion and compression curves will be assumed to follow Marriott's law.

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Draw the limiting lines of the cards, $O\,O'$, the clearance lines $S\,S$ and $S'S'$, the vacuum line $X\,X$, the back pressure line of low-pressure card $J\,D$, atmospheric line $Y\,Y$, and line of initial pressure $O\,A$. Then $\frac{120}{8} = 15$, locates H; and, A and D being given, draw expansion curves $A\,B$ and $H\,E$, and compression curve $D\,C$, carrying each of the latter up to the horizontal line through B. Then, knowing the cut-off in the low pressure cylinder, G is determined and $G\,L$ drawn. If, instead of the cut-off in the low-pressure cylinder being given, the receiver pressure, or more correctly, the initial pressure in the low-pressure cylinder, is given, G will still be determined by the intersection of this line with the expansion curve.

The line $G\,L$ depends upon three conditions, viz: the relative position of the cranks, the volume of the receiver, and the ratio of the cylinders. With receivers such as are ordinarily used, which consist of steam chests and connecting pipes between them, the back-pressure line of the high-pressure card will be practically horizontal, regardless of the position of the cranks. But with engines which have very small receiver volumes, this line, $G\,L$, must be located carefully, and as engines of this class almost always have their cranks at 180 degrees from each other, this line can easily be drawn as an expansion curve, using for the clearance volume the combined volumes of clearances of both cylinders; the total receiver volume, including all steam chests subject to receiver steam, and a volume $\frac{V}{R-1}$, when $V =$ volume of low-pressure cylinder, and $R =$ ratio of the cylinders.

Constructing a compression curve from F, finishes the diagrams, and the cylinder ratio is determined accurately by finding the ratio between the two lines $B\,K$ and $C\,E$, these lines representing the amount of steam in each cylinder. This is only true when all the steam which is exhausted from the high pressure cylinder appears in the low pressure.

By measuring a large number of cards from engines of various kinds, it was found that in ordinary single-valve engines with piston speed of about 600 feet per minute, with tight valves and

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pistons, without steam jackets, 90 per cent. to 95 per cent. of the steam exhausted from the high-pressure cylinder appeared in the low. With steam jackets this is increased to 95 per cent. and 100 per cent. Knowing this, it is easy to make allowance for it in getting the cylinder ratio.

If the cylinder ratio is given instead of the ratio of expansions, an assumption will have to be made after drawing the high-pressure expansion curve, for, until we know to what point the compression will be carried in the high-pressure cylinder, we cannot locate the point on line BK, from which to start the low-pressure expansion curve. The point E is located by measuring from C a distance equal to $\frac{BK}{R}$, R being the ratio of the cylinders. So we estimate the back-pressure line of the high-pressure card and draw the compression curve. If this estimate is in error it will be shown as soon as the low-pressure expansion curve is drawn, and with this as a guide the compression curve can now be drawn correctly and then a new expansion curve for the low-pressure card.

If it is desired to divide the range of pressures in the two cylinders so as to give about the same amount of work in each cylinder, the line GL must be drawn so that the areas of the two cards are to each other as the inverse ratio of the cylinders.

In assuming data from which to draw a set of cards, there are so many variable quantities that one method of procedure cannot fit all cases. The modus operandi in each case will, of course, depend upon the conditions which are assumed as a basis upon which to start. But if this general scheme is fully understood, there is no trouble in drawing cards to suit any case, when enough data is given to make the problem determinate.

The set of cards shown in Fig. 2, is drawn to show the use of this scheme as applied to cards for a triple-expansion engine.

After drawing the fixed lines as before, the high-pressure and low-pressure expansion, and the low-pressure compression curves are drawn, continuing the last two curves up to the line BK. The intermediate pressure card is left out of consideration at first. The point G is located as before, and then the back-

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pressure line and compression curve of the intermediate-pressure card can be drawn. The expansion curve for this cylinder can be drawn from either end. If a certain amount of "drop" at release is desired, the curve will be drawn from the lower end; if a certain cylinder ratio is desired, it will have to be drawn from the upper end, the ratios of the lines *BK*, *CE* and *MN* being the cylinder ratios. The completing of the diagram is the same as for the compound.

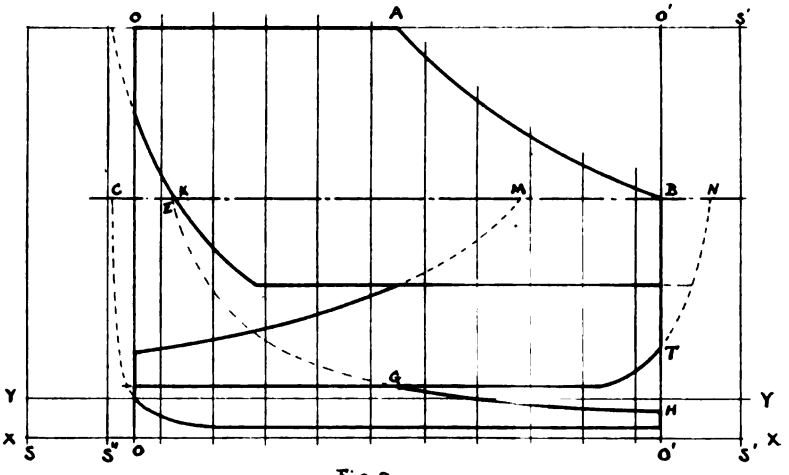

Fig. 2

If instead of the ratio of expansion, the cylinder ratios are given, the compression curve of the high-pressure cylinder will have to be estimated as was done with the compound-engine cards.

In drawing these cards, it has been assumed that the receivers are large enough to make the back-pressure lines of the cards parallel to the atmospheric line.

The following method of combining indicator diagrams was explained in a paper read before the American Society Mechanical Engineers by my father; it is contained in vol. xv, page 404, of the Transactions.

The method which is shown in Figs. 3, 4 and 5 consists in reducing the lengths of the cards so that they are to each other

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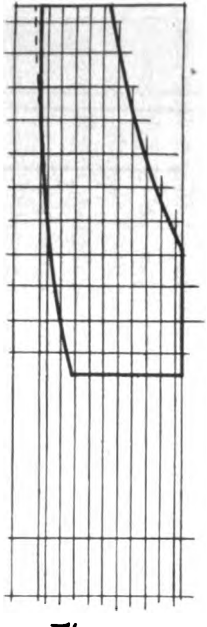

Fig. 3.

Fig. 4.

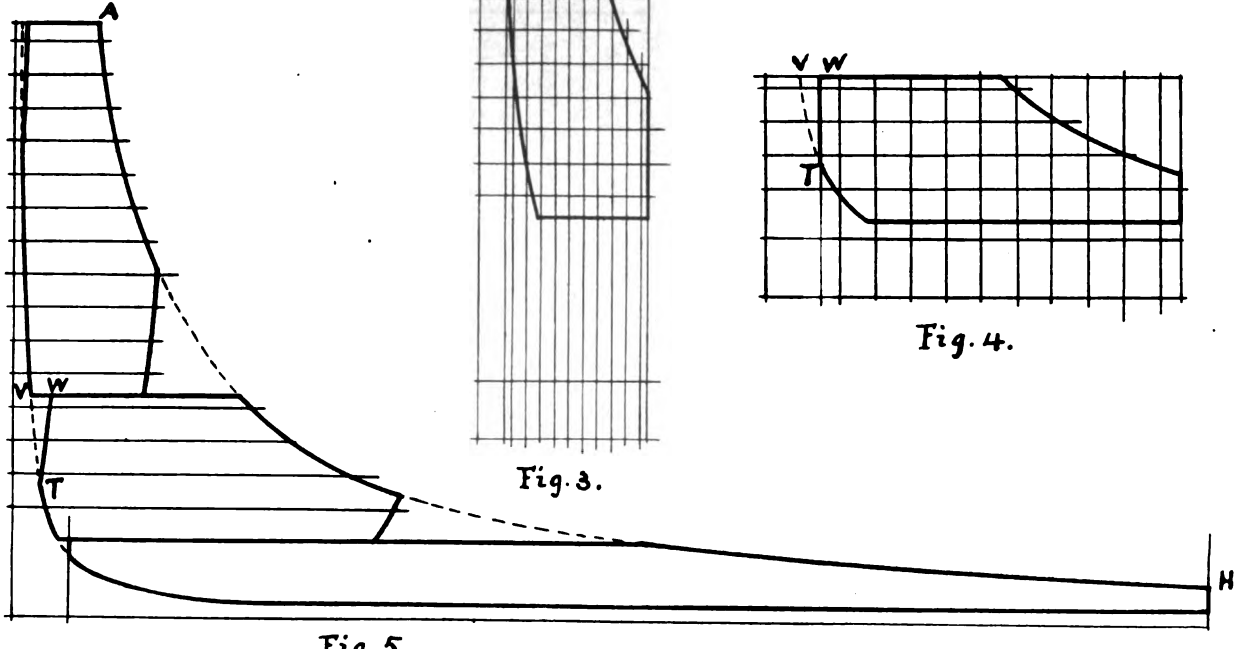

Fig. 5.

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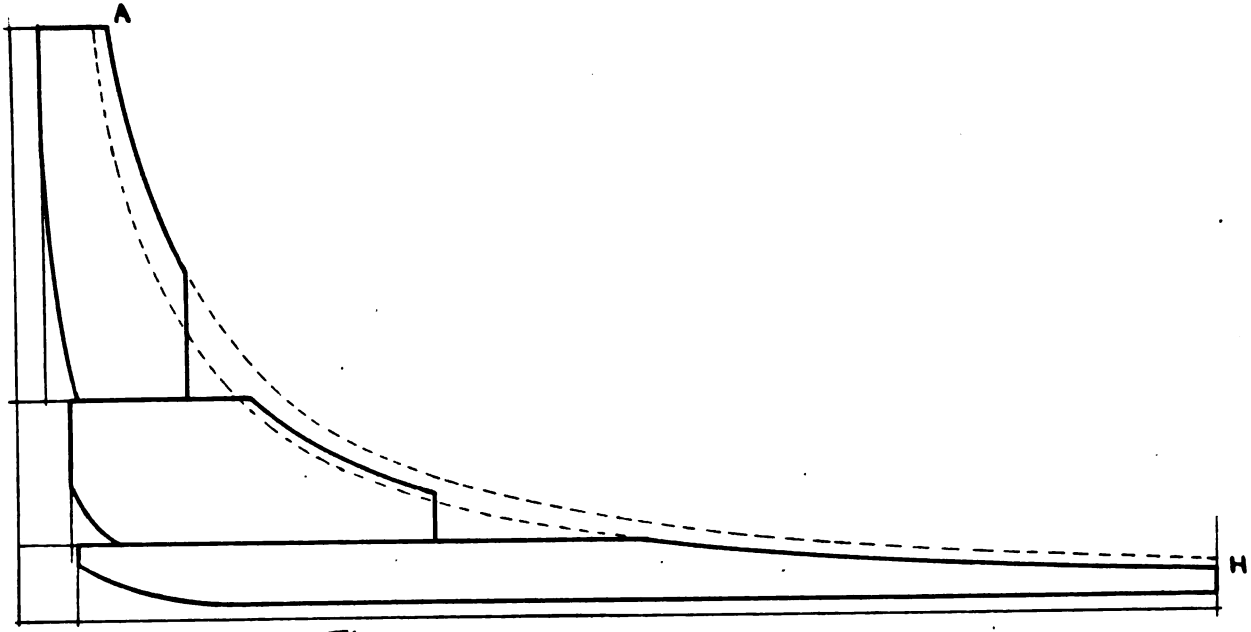

Fig. 6.

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as the cylinder ratios. If it is desired to refer them all to the low-pressure card, as is generally the case, the compression curve of that card is continued up to the top of the high-pressure card. Then the other cards are placed so that their compression curves match exactly this new compression curve, care being taken that all horizontal lines through the cards are the same length as before. An easy way to do this is to draw horizontal lines through the cards, as in Fig. 3, at intervals of say 10 pounds. On these lines measure from the compression curve, or this curve produced as *T V*, Fig. 4, to its intersection with the other side of the diagram, and transfer this length to the corresponding abscissa of the combined card. The line *T W* can then be located, and the diagram is complete.

These cards were originally constructed on the hypothesis that there are no losses, except by free expansion, into the clearance spaces at admission and into the receivers at release. These are the *only* losses which appear on the combined diagram, and it will be observed that the expansion curve is continuous, fitting the expansion curve of each diagram exactly. This will always be true, no matter how widely the clearances in the different cylinders may vary. With diagrams combined in this way, it is easy to see where the losses are, and to measure accurately their amounts.

Fig. 6 shows these same cards combined in the usual way of reducing the cards to their proper length and then superposing the clearance lines. It can be seen at a glance how crude this method is, for here we have cards which are constructed on the hypothesis that there is no loss or gain of steam from one cylinder to the other, and yet an expansion curve from the high-pressure card does not fit either of the other expansion curves at any point. There is nothing really wrong with this method, for the cards are just as true in this form as they were before; but the only object of combining them is to get some additional information from them in regard to the continued expansion from one cylinder to another, and to ascertain what percentage of the ideal diagram they realize. As neither of these things is

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shown with any degree of accuracy, practically nothing is accomplished.

To show this more clearly, the expansion curve is continued from the high-pressure card to the end of the low-pressure card, and one is also constructed from the low-pressure to the top of the high-pressure. Neither of these curves fit the expansion curves of either of the other cylinders at any point.

In engines having small and uniform clearances, this method gives fairly accurate results, but in marine work and all other work where the clearances are necessarily large it seems to be a waste of time to use a method which is so much at fault.

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ELECTRICAL PROPULSION FOR TORPEDO BOATS.

By Prof. W. F. Durand, Member.

The application of electricity to marine propulsion has in recent years attracted the attention both of electrical and marine engineers, and the successful operation of the electric launches at the World's Columbian Exposition in 1893 gave to many strong hopes that the field of such application might be immediately widened to include small craft of all descriptions and for all purposes, and that the day was not far distant when even large craft as well, the liner, the freight steamer and the warship, would all derive their propulsive power from energy stored in the electric form. It was early recognized, however, that energy embodied in storage batteries is excessively expensive in weight as compared with energy embodied in coal, and furthermore that electric motors are usually heavier for the same power than the lightest types of steam engines. These facts introduced a prompt limitation to the extension of electric propulsion, especially to cases where high speed or long endurance was desired.

In a paper published several years ago * the author showed the limitations and presented the possibilities of electric propulsion as given by the practice of that day. It may not be without interest to reconsider the same subject briefly, and to note what advances have been made since the publication of that paper. Especially may this be suitable at the present time in connection with the appearance of an article in the last number of the Journal by Mr. C. T. Child on the same subject.

The data which are used in the latter article and which are made the basis of the case as presented, seem to be considerably beyond current American practice, and undue expectations may perhaps be awakened regarding the readiness with which such results could be realized.

* Cassier's Magazine, June, 1895.

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In regard to the fundamental values assumed for the torpedo boat it may be said that the power is perhaps a trifle low for the displacement and speed, and the fraction of weight available for machinery and propulsive equipment rather high, both tending, of course, to make a better case for the electrical equipment. These differences, however, are not of particular importance, for the question of the availability or otherwise of an electrical equipment rests on considerations of a more serious and fundamental character.

Let us then proceed to a comparison between an electrical and a steam propulsive equipment, using in addition to the data taken by Mr. Child, such additional safe values from modern engineering practice as might naturally be made the basis of a business contract. We need first to specify units of *power* and *work* relative to which the comparison may be made. For these we shall take respectively the *horse power* delivered to the screw shaft, and the *horse power per hour* delivered to the screw shaft.

For the steam equipment we may allow 2.5 pounds coal per H.P. per hour on the shaft. This will occupy about .05 cubic feet bunker space. For the total weight of steam equipment, including engines, boiler and auxiliaries all in steaming condition, we have values ranging from 40 pounds to 70 pounds per power unit on the shaft. Of this amount the engine-room weights furnish rather less than one-half and the boiler-room weights rather more than one-half.

Turning now to the electrical equipment, we must examine the weights of batteries and motor for the same units on the shaft. Taking first the batteries, we must distinguish two questions:

(1.) How much battery is necessary in order to actually attain a certain desired power, aside from the question of endurance?

(2.) How much battery is necessary in order to embody a given amount of energy, aside from the question of how rapidly it is used or how much power is developed?

The two questions are not independent, and must be examined together.

In Fig. 1, AB shows the nature of the relation between the

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total capacity of a storage battery and the time of discharge, while *A C* shows the corresponding value of the discharge current. Beyond three or four hours the total capacity more slowly increases with the time, as shown, while for a shorter period the total amount which can safely be taken from the cells quite rapidly falls off. The power which can be developed depends, then, simply on how rapidly the cells can be discharged, and is, of course, proportional to the discharge current, as shown by *A C*.

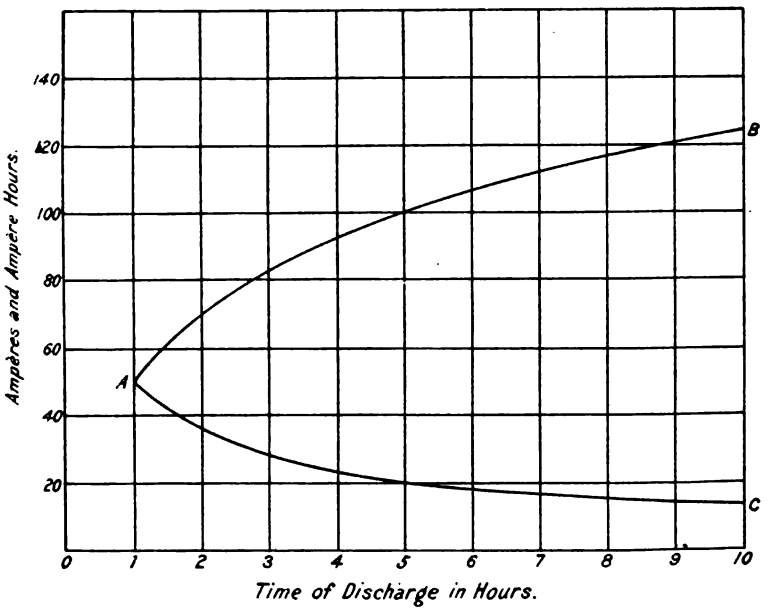

FIG. 1.

Capacity in ampère-hours and corresponding current in ampères for varying time of discharge. For relative purposes the capacity at five-hours' discharge is taken at 100 ampère-hours.

The limit to the development of large power from a small battery is, therefore, the increasing danger of damage to the cells resulting from excessive rates of discharge, and the rapidly decreasing time during which the power is available. The normal discharge period is usually taken at from eight to ten hours, but with care it may, with the best types of cells, be safely decreased to four or five hours. For a few moments the discharge current

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may even be increased far beyond the values corresponding to these periods, but for what may be termed continuous conditions a rate corresponding to discharge in four or five hours is about the maximum usually employed.

If we take now the weights of the leading American storage cells as built for stationary purposes, and derive for the various rates of discharge the weight per *horse power per hour* of battery output, and of weight per *horse power* of output, we shall find values as represented by *A B*, Figs. 2 and 3, respectively. The increase of weight per work unit as well as the decrease of weight per power unit, as the time of discharge is decreased, are both clearly shown by the diagram. In these cells the weight of the

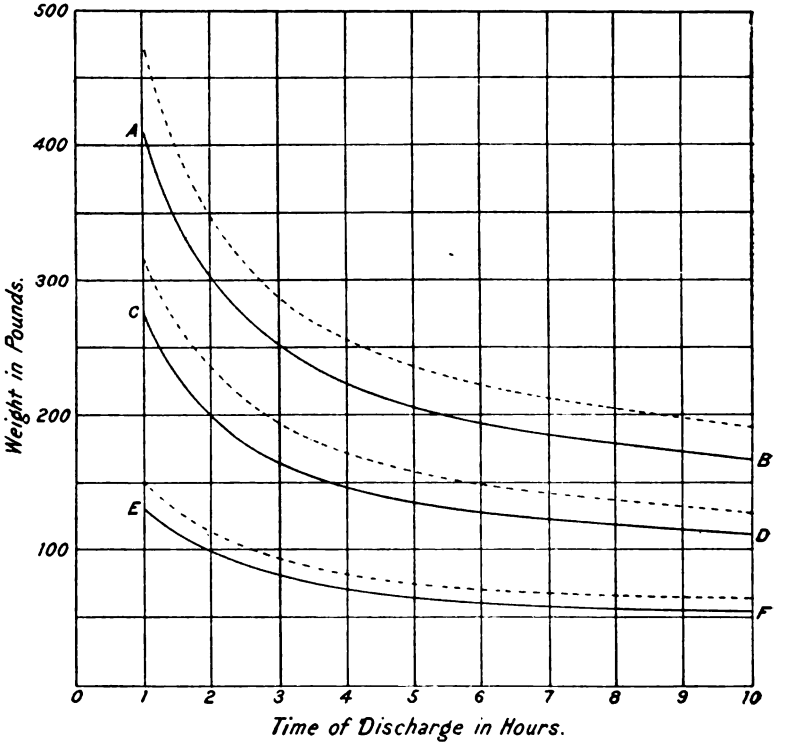

FIG. 2.

Weight of batteries per H.P. per hour for varying time of discharge.

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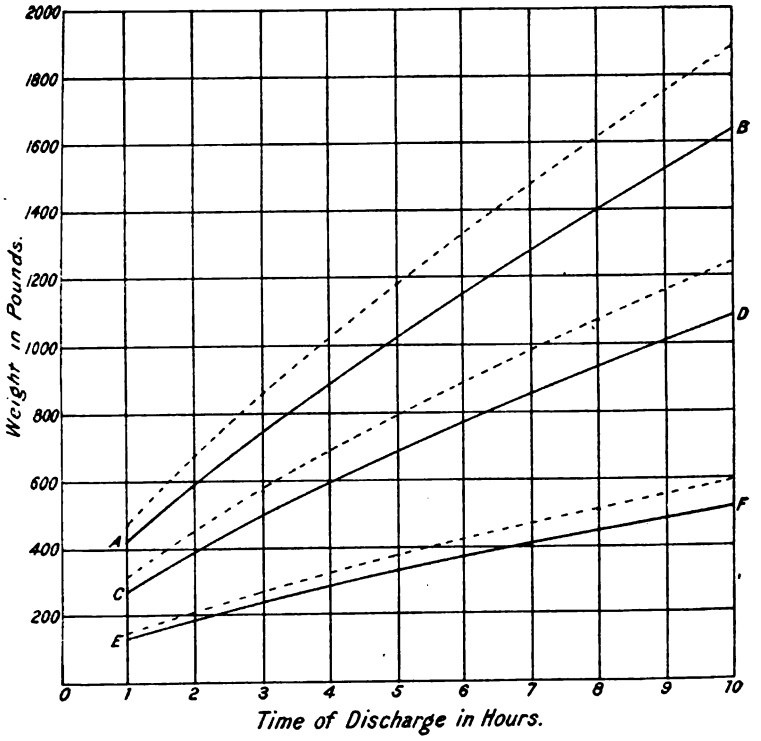

FIG. 3.

Weight of batteries per H.P. for varying time of discharge.

lead elements is from 50 to 55 per cent. of the cell complete with acid and lead lined wooden tank. In a somewhat lighter form of construction for cells of the same type the weight of the lead elements is about 65 per cent. of the cell complete, and the latter ranges at about two-thirds of the values shown by the curves, *A B*. These lower values are shown by the curves *C D* on the same diagrams. These figures and diagrams show what may be expected from commercial cells at present on the American market. As to possible reductions in the weight of this type of lead cell, the future alone can determine. It is a significant fact, however, that these cells as built at the present day, are considerably heavier than those on the market a few years ago. This

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seems to indicate that for purposes of durability, reliability and continuity of operation, the heavier type of construction is preferred where the additional weight is not a special disadvantage.

Turning now to the results given by the report of the French tests of automobiles, as referred to by Mr. Child, we find an entirely different range of figures. In these cells the normal period of discharge is taken as five hours, and the figures for power output and capacity refer fundamentally to this period. At the same time the capacities for a discharge current double and half the normal value are also stated. These correspond to periods of about two and eleven hours. Between these limits the resultant capacity curve plotted on time agrees fairly well with similar data derived from American practice, and the curve *A B* of Fig. 1, which represents a series of mean values drawn from a considerable range of recent American data, may probably be taken as representing satisfactorily the relative capacity curve for the automobile battery as well.

In this battery the weight of the lead plates is about 70 per cent. of the cell complete. For the latter, the weight per horse-power output for a five-hour discharge is 321 pounds, and per horse power per hour output, sixty-four pounds. It will be seen that these figures are from about one-half to one-third those for the cells on the American market. They are represented by the curves *E F* in Figs. 2 and 3. As to how far it would be safe to expect that this lighter type of construction would be suitable for marine propulsion, it is difficult, from the description given, to form a satisfactory opinion. Until more evidence is forthcoming, however, their suitability to such uses may be fairly open to some doubt.

With regard to the space occupied, and basing the total out-put on the five-hour discharge, we find for the American cells a space of from 1 to 1.4 cubic feet per horse-power per hour output, while for the lighter automobile cells the space required is about .5 cubic foot, or about in the same proportion for space occupied as for weight.

It will be noted that the above figures for batteries all refer to

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output. Assuming a motor efficiency of .87, we may reduce to similar units on the shaft by dividing by this ratio, an operation which will increase the several figures by about 15 per cent. of their former values. A uniform efficiency as high as .87 is more than can be expected, especially for the extreme conditions, but the error favors the electrical equipment, tends toward simplicity of treatment, and is not significant for the purpose in view which is not so much to take account of all secondary influences as to show the general character of the results to be expected under the various suppositions made. In Figs. 2 and 3 the increased weights are shown by the dotted lines. For the space occupied the figures will be from 1.15 to 1.60 cubic feet per H.P. per hour for American batteries and about .58 cubic foot for the automobile battery.

Turning now to the motors, we find a wide variation in figures. During the past five years some advance has been made in the reduction of weights, and, taking values representing the best actual practice, we find from 30 to 50 pounds and upward per H.P. on the shaft. The minimum figures correspond to revolutions per minute of not over 400 or 500 for the larger sizes. Some further saving might still be made by an increase of revolutions, but such saving is limited, for the weight of motors by no means decreases as the revolutions increase. Heating in the armature and poles, and structural considerations connected with the necessary space for insulation, etc., place an early limit on the reduction of weight by increase of revolutions. As suggested by Mr. Child also, some further reduction might be made by more extended use of laminated iron in the field, but it may be fairly questioned whether so large a reduction as that implied in the figures given in his article could be hoped for. In any event, so far as the author is aware, motors weighing only 16 pounds per unit of horse power output are not the subject of current design, they are not on the market, and it is doubtful if reliable builders would care to guarantee weights much below the minimum stated above. If we take the best of present-day practice as represented by motors actually built and ready for use, we shall not be able to go much below 30 pounds per horse-power on the shaft for such motors as would be suitable for purposes of marine propulsion. We will, however,

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assume 25 pounds as presumably obtainable at the present time by special design.

Taking the figures given above it results that for equal amounts of work delivered to the shaft, storage batteries, on the basis of a five-hour discharge, weigh from thirty to nearly one hundred times as much as coal, and occupy from ten to thirty times as much space.

For the same power delivered to the shaft, the electric motor will weigh somewhere about one-half the total weight for a steam boiler and engine, and rather more than the engine-room equipment alone.

It is quite evident that in an electrical equipment the weight of battery will be the chief item, and that the necessary weight will be determined by the maximum power required and by the safe rate of discharge at which this power may be developed.

If the maximum speed of the boat is to be considered as 22 or 25 knots, then in order that such a term may have any significance in a tactical or naval sense, it should be possible to maintain this speed for at least one hour and, preferably, more; and it would seem unwise to use in the development of such a speed for a period of an hour or more, a discharge current higher than that corresponding to a four-hour complete discharge. It is true that a boat thus equipped could make rushes of short duration at a much higher rate of speed, but to be of tactical value their safe duration should extend beyond periods of a few minutes. It may be here noted that in the report of the French Commission on automobiles, the maximum discharge considered as allowable for anything beyond momentary rushes of current is that corresponding to complete discharge in about 3¼ hours, a current one-third above the normal for a five-hour discharge. A further limitation arises from the rapid loss of safe total output at excessive rates of discharge, so that the relative endurance rapidly decreases as the discharge current is increased.

Thus, according to the law indicated in Fig. 1, a doubling of the discharge rate for a four-hour period will reduce the endurance to one-fourth its value, or to about one hour. The qualities

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of a torpedo boat and the conditions which she should fulfill are, of course, largely matters of opinion; but taking into consideration questions of tactics and safe endurance, it would seem as though a requirement of full speed for one hour at a discharge rate not exceeding that for a four-hour endurance, or a possibility of full speed for four hours, is little enough to require of a boat intended to meet the probable exigencies which may attend the operation of such craft. Taking the values from Fig. 3 for a four-hour discharge, we find that for a 140-ton boat, with 2,000 shaft H.P., the weights required would be, for American batteries, from 1,400,000 to 2,000,000 pounds in round figures, and for the automobile battery about 650,000 pounds. In any case the weight required is several times the total displacement of the boat, and hence entirely out of the question. For 1,500 H.P. the weights would be three-fourths of the above amounts, and hence equally unattainable.

It is thus clear that the requirements as laid down, and as they might naturally be taken, having in view the results attained by steam equipment, are entirely out of the question. Even in the case of the automobile battery, regarding the suitability of which we may still reasonably doubt, the weight required for batteries alone is about twice the total displacement of boat. We may then naturally, as does Mr. Child, approach the question from another standpoint, and, taking a certain amount as disposable for motor and batteries, investigate the possibilities.

To this end let us assume that the motors are to be rated normally for the power which would be developed with the two-hour discharge current. They could then stand, for short periods, increased rates of discharge up to that corresponding to a one-hour endurance. This would provide for the possibility of short rushes at excessive rates of discharge and developed power, and the motors would, of course, be more than ample for lower rates and longer periods of endurance. For a two-hour discharge current, according to Fig. 3, American batteries will weigh from 440 to 660 pounds per H.P. on the shaft, and the automobile battery about 210. Adding, say twenty-five pounds

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for motor, we should have respectively the figures 465 to 685, and 235.

Out of the total displacement of 140 tons we will take, for our present purpose, the same amount as that assumed by Mr. Child, viz: 201,000, as disposable for motors and battery. Dividing this weight by the above figures, we should find for the rated motor powers, respectively, 293 to about 430 and about 850. The corresponding motor weights would be, respectively, 7,325 to 10,750 and 21,250. The balance available for battery would be, respectively, in round numbers, 194,000 to 190,000 and 180,000, and on the basis of the laws expressed in Figs. 1 and 3 we might expect results somewhat as given in the following table:

Time of complete discharge.	Heavier American Battery.			Lighter American Battery.			Automobile Battery.		
	Power.	Speed.	Endurance.	Power.	Speed.	Endurance.	Power.	Speed.	Endurance.
1	412	15.2	15.2	618	17.2	17.2	1,320	21.0	21
2	290	13.6	27.2	435	15.5	31.0	929	19.5	39
3	228	12.7	38.1	342	14.4	43.2	730	18.0	54
4	190	12.0	48.0	285	13.5	54.0	609	17.0	68
5	164	11.4	57.0	246	12.9	64.5	525	16.4	82
10	103	9.9	99.0	155	11.2	112.0	330	14.1	141
24	52	8.0	192.0	78	9.0	216.0	167	11.5	276

A boat with capacities as given by these figures may be made use of in a variety of ways, but even in the most favorable case such a craft is not a torpedo boat. So far as the use of the results from the report of the French Commission on automobiles is concerned, the chief difference between these figures and those derived by Mr. Child is in the possibilities at excessive discharge rates. Experimental information on this point does not seem to be given in the report. The normal rate of discharge was considered to be that for a five-hour period, for which the figures as taken from the report have been given above. In addition, statements were made regarding the capacities at double and half the

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normal rates of discharge, as previously noted. In the actual tests as shown by the time of run and by the graphic logs of the discharge currents, the mean rate was only slightly above the normal, though momentarily it rose to values two or three times as great. The general law connecting safe capacity with time of discharge, as shown in Fig. 1, and particularly for very small periods, has been already referred to; and extending such general law to the lighter automobile cell, it follows that the expectation of 2,000 H.P. for one hour, based on the actual performance of about 500 for five hours, is far beyond what is likely to be realized. This would require a safe capacity for one hour of about 80 per cent. of that for five hours, an assumption requiring the same general rate of decrease between five hours and one hour as is usually found between eight or ten hours and five hours. Available data shows that this expectation is far from any probable realization.

Even if the automobile battery were found well suited to marine propulsion and the full results as derived by Mr. Child were obtainable, the resulting boat would be of problematical value, for the utility of a torpedo boat with an endurance of only 25 miles at full speed may fairly be called in question. What should we think of a like torpedo boat with steam equipment developing 2,000 horse-power, and carrying only about two tons of coal instead of twenty or thirty?

Let us now turn briefly to the possibilities under steam equipment with the same weights available for propulsive purposes. Taking the total weight of 213,000 pounds, as assumed by Mr. Child for motors, batteries and controlling devices, we will first assume 30 tons of coal. This leaves 145,800 pounds available for steam machinery. Without going to the extremes of light construction this would provide for the development of from 2,500 to 3,000 I.H.P., giving from 2,200 to 2700 H.P. on the shaft. Taking again only 10 tons of coal as corresponding to trial conditions, we should have 190,600 pounds available for steam machinery, which would provide for the development of from 3,000 to 3,800 I.H.P., giving from 2,700 to 3,400 on the shaft. These figures correspond closely to the latest Navy Department designs

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for torpedo boats, where, with 150 tons displacement, 3,000 I.H.P. are to be developed on 178,600 pounds, giving practically 60 pounds per I.H.P. Merely as a matter of comparison with the electrical equipment it would not be unfair to reduce the coal to the amount necessary for one hour at full speed. If short endurance is admissible in one type of boat it should not be denied the other. This would reduce the coal to about four tons, leaving 204,040 pounds for steam machinery, on which from 3,400 to 4,000 I.H.P. could be developed, giving from 3,000 to 3,600 H.P. on the shaft. Of course no one would think seriously of a boat with so small a coal supply, but for comparative purposes it serves to show how wide is still the gap between the possibilities with steam and electrical equipment. With the former we readily develop three times the power possible with the latter, even under the best conditions furnished by the automobile batteries, and from six to eight times the amount under the best conditions given by the standard batteries on the American market. On this point it should be said that these batteries are intended for stationary use, and are not designed or built with a particular view to the saving of weight. With the latter point in view, doubtless a lighter type of construction could be developed, and the figures for the French automobile battery reproduced. The durability and adaptability to marine propulsion of such a battery would still be an open question, and only to be settled by the appeal to experience. All this, however, as we have seen above, would still leave the electrically-driven torpedo boat far from a reality.

The subject of cost should also be noted in connection with the general comparison between these two modes of torpedo-boat propulsive equipment. Mr. Child makes the statement that the cost would be about the same in either case. It is hard to find prices which verify this statement. Steam machinery complete may be built for from $20 to $25 per I.H.P., or from say from $22 to $27 per shaft horse power. The electric motors, including switches, controlling devices, etc., will very nearly cover these figures, leaving the first cost of the batteries practically without an offset in the steam equipment.

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Recent net quotations on American storage batteries were on the basis of about $9 per 100 ampère hours for a five-hour discharge. In large quantities we might expect a reduction, but probably not below from $6 to $7 for the same unit. This would correspond to from $24 to $28 per H.P. hour on the shaft, or from $120 to $140 per H.P. on the shaft for the five-hour discharge. Taking for commercial American cells the possibilities in the present case at about 200 H.P. for five hours, or 1000 H.P. hours, we should have for battery alone say $25,000. Taking the motor as rated at 350 H.P., its cost would be, perhaps, about $7,000, thus giving $32,000 for the electrical equipment. A 350-H.P. steam equipment complete could be provided for from $8,000 to $10,000.

Regarding the cost of energy in storage batteries it appears that, taking into account the losses incident upon the various transformations through which it is passed, that mechanical energy delivered to the shaft by a motor from a storage battery will cost nearly twice as much in pounds of coal at the steam engine which charges the cells, as it would if delivered direct from the engine to the shaft. That is, for equal amounts of work on the shaft, electrical propulsion will require the initial consumption of nearly twice as much coal as with the steam engine coupled direct to the screw shaft, the two engines concerned being of about equal efficiency.

There are still other questions which may affect the application of electricity to torpedo-boat propulsion, such for example as the need of protecting both cells and motors from salt water, the need of closing in the cells so as to prevent spilling of the acid due to rolling, questions of durability, repairs and renewals, questions relating to the dependence of a boat upon a generating set as a base of supplies for recharging the cells, etc. These are, however, of secondary importance in comparison with the fundamental question of what can be done, granting that all secondary questions are supposed to be favorably answered. The present paper is concerned with this fundamental question rather than with those of secondary importance. All special discussion of torpedo-boat tactics or of the special suitability or otherwise of

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limited endurance to torpedo-boat service have been also left aside as unnecessary to the main purpose of the paper.

There are, of course, many special advantages connected with electrical propulsion, such as relative noiselessness and freedom from vibration, absence of smoke or flame, safety from disastrous explosion, instantaneous readiness for use so long as charged, etc., and it is to be most strongly regretted that the limitations are of such a character as to render the possibility of availing ourselves of these features dependent upon a reduction in the weight of storage cells which at present seems hopelessly beyond reasonable expectation. When it is realized that the light French automobile cell weighs some three hundred times as much as coal for equal energy stored, and some thirty times as much for equal amounts of work at the shaft, it is clearly apparent that so long as these relations hold the storage cell cannot hope to displace coal for marine propulsion except in those cases where moderate speed and short endurance are not objectionable. To our present-day judgment it would seem that if energy stored in the electrical form is to rival in compactness that stored in coal, it will require a development along some line entirely different from that represented by present-day storage cells.

What developments in these lines the future may hold for us the event alone can determine, and should the day soon come when electricity can be satisfactorily and efficiently employed for the attainment of the highest results in marine propulsion, probably none will be more ready to welcome the change than those who see in its present-day limitations an insuperable bar to its use at the present time.

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AUTOMATIC STOKERS FOR MARINE USE.

The proper and scientific method for governing the combustion of fuel unquestionably has absolute regularity of supply and distribution, both of fuel and air, as a primary feature. Wherever man is alone depended upon to control continuous operations of this kind there will always be found a large though varying per cent. of loss due to carelessness, forgetfulness, ignorance, fatigue or indolence, singly or in combination, and it is for this reason that engineers have always looked to automatic devices to eliminate as far as possible these losses. If by mechanism he can reduce the number of separate operations to be performed by a fireman, he reduces equally the chances of failure to carry out the functions properly.

In the burning of coal in boiler furnaces skillful and scientific firing is always attended by difficulties which increase with the quantity to be burned per square foot of grate as well as with the character of the fire rooms. Thus, on shore, where ample space is allowed for boilers and furnaces, and the ventilation good, the work is far easier to perform well than it is in the "hell hole" of a torpedo boat. Practically, under forced-draft conditions afloat, firing only approximates the ideal, and it is seldom that either the supply of fuel is of proper frequency and quantity; generally the fault being the greater quantity at a charge and at too long intervals. Attention to the supply, as ordinarily practiced, also involves losses through this interruption of the cycle of combustion and adds other bad features by the surplus volume of cool air admitted through the fire doors.

The inventions for conducting "automatic stoking," therefore, have not been few, and probably their adoption in many land plants came through a desire to economize in reducing the number of employees rather than in order to obtain better results from the fuel burned. Here, almost any practical device could

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be experimented with, but up to recently there appeared always to exist features which rendered the appliances wholly inapplicable to use on shipboard where furnaces are of such limited height and width, and the angle of grate with the horizontal line so variable, owing to the rolling of the ship.

The "Marine Review" of December 15th, 1898, called attention to the fact that the Zenith Transit Company, of Duluth, were to instal automatic stokers (The American Stoker) on their new big 7,000-ton freight steamer in connection with Babcock & Wilcox boilers, and inquiry has led us to present the principal features of this stoker here, prior to the actual experience they are to have, and dependent upon which criticism is reserved. Merely as a possibility, the appliance is interesting to marine engineers, and the obviously objectionable features or faults are also left to individual study. In presenting the following description of the apparatus, taken from the company's illustrated circular, attention only is called to the cross section of the fire (understood by following the description carefully), and to the matter of cleaning fires; also to loss of fresh water by exhausting steam from the motors into the ash pan, this latter no doubt being easily obviated in marine installations. In this particular installation three of these stokers are to be placed in each furnace, the magazines being each 24 inches wide, and a dead grate of 18 inches separating each magazine from its neighbor; also a dead grate of 12⅝ inches between the side of each outer magazine and the side of the furnace. Of course each magazine is the full length of the furnace.

Mechanical stokers and patent furnaces are divided, by reason of the principle upon which they operate, into two classes: those "overfeeding" the coal and those "underfeeding" the coal. The former are new adaptations of the principle used in the plain grate-bar furnace. The weakness of common grate-bar practice is recognized from the fact that, following the natural draft, the greatest quantity of air is admitted through the grate at points where the coal bed is thinnest, whereas the most air is needed where the coal bed is heaviest. The coal thrown on a hot fire releases its gases very quickly, and if there be an insufficient quantity of air

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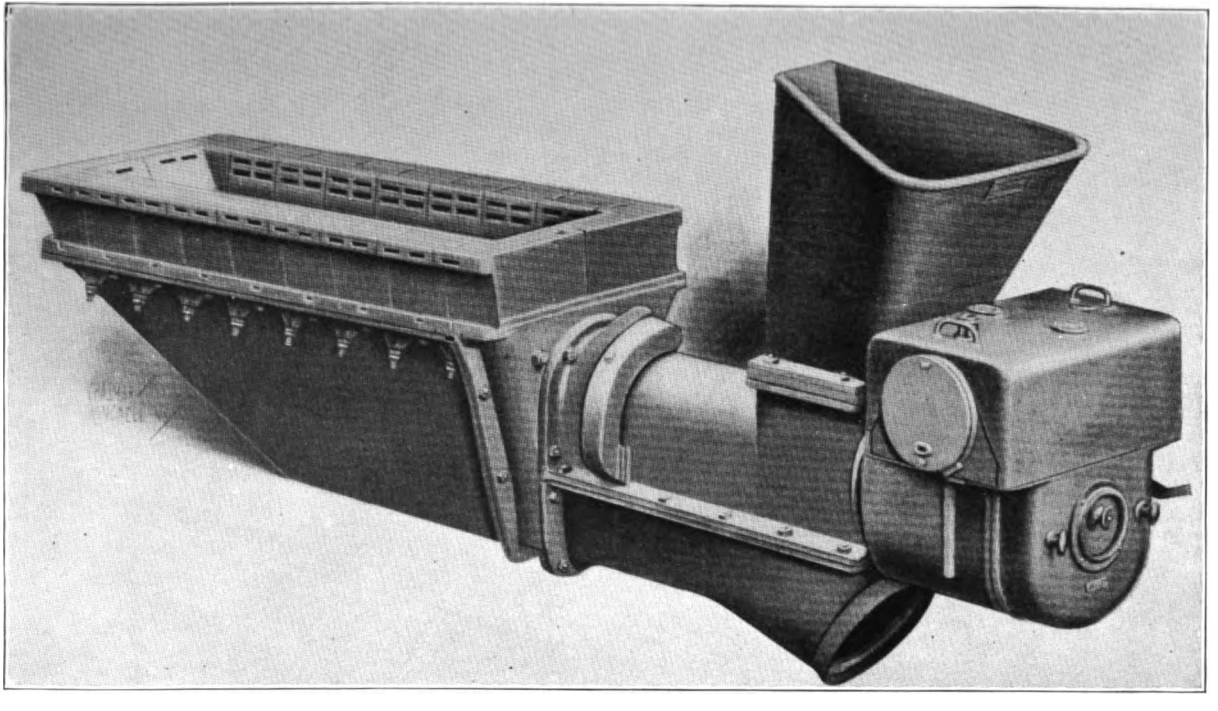

FIG. 1.

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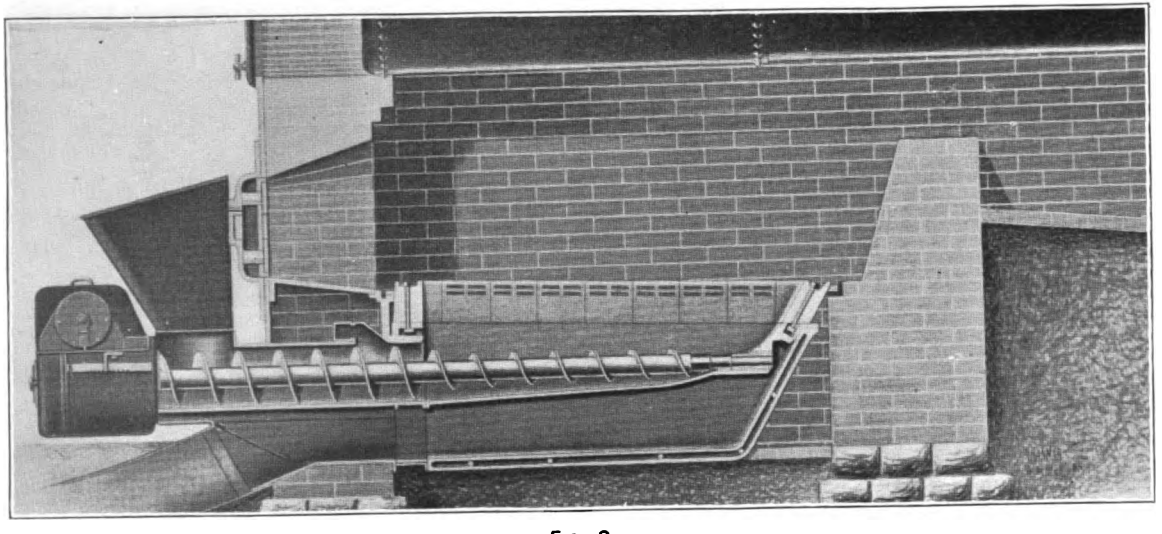

FIG. 2.

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at this point of release, these gases pass off unconsumed, causing smoke. The "overfeed" stokers and furnaces seek to overcome this by mechanically feeding the coal in small quantities in such manner as to evenly distribute the coal, thus causing a more even admission of air.

The American Stoker is of the "underfeed" class, and is here illustrated (Fig. 1), completely assembled and ready for installation. Immediately beneath the coal hopper, and communicating with it, is the conveyor pipe; this in turn communicating with the coal magazine. A screw conveyor or worm is located in the conveyor pipe and extends the entire length of the magazine, as shown in Fig. 2. Immediately beneath the conveyor pipe is located the wind box, having an opening beneath the hopper. At this point is connected the piping for the air supply, furnished at low pressure by a blower. The furnace end of the wind box opens into the air space between the magazine and its outer casing. The upper edge of the magazine is surrounded by tuyeres, or air blocks, these being provided with openings for the discharge of air, inwardly and outwardly.

Each stoker is driven independently by a small steam motor, located immediately in front and beneath the hopper. The motor has a simple reciprocating piston. Its piston rod carries a crosshead, which, by means of suitable connecting links, operates a rocker arm having a pawl mechanism, which in turn actuates a ratchet wheel attached to the conveyor shaft. The stoker is thus entirely self-contained and complete in itself, and consequently there is no danger of the driving and feeding mechanism (the only working parts) ever getting out of alignment. The rate of feeding coal is controlled by the speed of the motor, this being effected by the simple means of throttling the steam in the supply pipe to the motor. The shields covering the motor effectually protect the mechanism from dirt and dust.

No special furnace setting is required. It is only necessary to change the location of the rear bearing bar to suit the length of the stoker, and to introduce the conveyor pipe through the front. The stoker rests on the front and rear bearing bars; the space between sides of stoker and side walls is filled with iron plates,

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termed "dead grates." Steam is carried to the motor by a ¾-inch steam pipe. The exhaust steam from the motor is discharged into the ash pit.

The coal is fed into the hopper, carried by the conveyor into the magazine, which it fills, "overflows" on both sides, and spreads upon the sides of the grates. The coal is fed slowly and continuously, and, approaching the fire in its upward course, it is slowly roasted and coked, and the gases released from it are taken up by the fresh air entering through the tuyeres, which explodes these gases and delivers the coal as coke on the grates above. The continuous feeding gives a breathing motion to this coke bed, thus keeping it open and free for the circulation of air.

Every pound of coal fed into the hoppers passes through this gas-making process, and there is no loss of coal through grates, by reason of the use of dead grates in the furnace in place of open grate bars. The non-combustible is taken from the furnace, necessarily from the furnace doors, in the shape of vitrified clinker. There is practically no soot.

Ability to feed the finest of slack coal and also handle lump coal is claimed, as any lump that can be fed into the hoppers will be crushed by the conveyor, there being provided a set of teeth, placed at the mouth of the conveyor, against which the coal is squeezed and broken.

Using the grades of coal found in and east of the Pittsburg coal district, fires need not be cleaned oftener than once every twelve hours. Ohio, Indiana and Illinois coals of low grade generally require cleaning once in eight to ten hours. All depends on the quantity burned.

The non-combustible takes the form of vitrified clinker, deposited in a form like a cake on the grates next the wall, being "shed" to one side by the constant upward feeding of the coal. One open grate against each wall admits air and steam from below (the steam being the exhaust from the motor), and this prevents the clinker sticking to the walls.

To clean, a slice bar is run along over the grate, the clinker raised and drawn out with a hook. The central part of the fire is never disturbed. The constant feeding does all the stoking

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necessary. The fire doors are never opened except when cleaning, thus avoiding the cold inrush of air, so damaging to the boiler tubes and sheets.

The exhaust steam from the motor is discharged into the ash pit. One fireman can readily handle four stokers, shoveling his own coal. With mechanical coal carriers along the front of the boilers, one man can handle from twelve to fifteen stokers.

It has been found that the ordinary steam jet, so often used in connection with smoke-preventing devices, takes from 10 to 15 per cent. of the steam made by the boiler. The steam used in actuating the motor on this stoker is stated to be less than twelve one-hundredths of a horse-power, and adding to this the steam used in the actuating of the blower, the total charge for the actuation of a stoker equipment can be estimated at about 1½ per cent. of the steam made, and adding to this the reduced cost of firemen for handling the coal, the total cost of the actuation of these stokers is far below that of ordinary hand firing.

The practicability of any stoker depends upon its cost of maintenance. No mechanical part of the American Stoker is subjected to intense heat. The tuyere blocks alone come in contact with the fire, and these are protected by the constant circulation of air. These blocks are common iron castings, weighing but twenty-four pounds each, and are readily replaced or renewed.

The conveyor shaft is a 2¾-inch steel shaft, on which are strong "flights." These flights, by their decreasing diameters, distribute the coal equally over the entire width and length of the furnace. The entire mass of coke above the tuyere blocks and over the side grates is ignited. The depth of the bed of burning coke above the tuyere blocks is from 14 to 18 inches. The air enters the stoker from the front beneath the hopper, passes through the wind box and discharges through the tuyere openings. The discharge of air into each stoker is regulated by a wind gate located at the mouth of the wind chamber.

In an average setting the stoker mechanism extends 33 inches in front of boiler front.

While the presence of smoke at the stack indicates imperfect combustion, yet it must not be taken as an evidence of great

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loss. A stack may be smokeless, and yet the dilution of the gases, by reason of too great a supply of air at the furnace, may be such as to be causing a great loss.

The principle upon which the American Stoker operates, practically reducing the coal to gas and coke, and passing all products of combustion through an incandescent coke bed, is a guarantee of freedom from smoke and soot.

The tendency exists in all ordinary furnace practice to burn "blow holes" in the fire. The greatest amount of air will enter through a common grate at a point where the fire is thinnest, and at which point the least amount of air is required; while at the point where the bed of coal is thickest, where the greatest amount of air is required, the least is supplied. The continuous feeding action of the stoker in a remarkable degree overcomes this natural difficulty. The air being supplied under mild pressure of from 1 to 1½ ounces, passes through the burning coal, and is brought intimately in contact with the incandescent coke.

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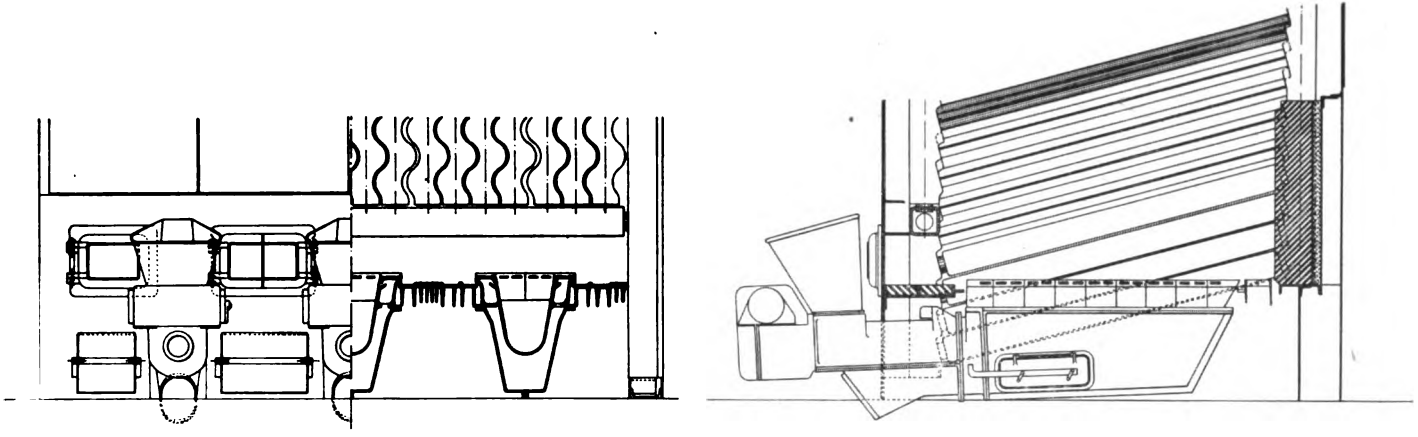

THE BABCOCK AND WILCOX WATER-TUBE BOILERS FITTED WITH AUTOMATIC STOKERS FOR THE ZENITH TRANSIT STEAMER.

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TEST OF A DIESEL MOTOR.

Supplementing the valuable paper of Col. E. D. Meier on the Diesel Motor, published in the February, 1898, number of the JOURNAL, we here give a synopsis of a report as recently printed in the "Engineering News," by Professor James E. Denton of the Stevens Institute of Technology, presenting the principal results of a series of economy tests of a Diesel motor, rated at 20 brake H.P., using various kinds of oil as fuel. The motor is one of the first made for the market in Germany, and is the first that has been brought to this country. It was erected at the Electrical Exhibition held last spring in New York city, where it drove an electric-light plant for five weeks. It was then erected for the purpose of the tests at No. 24 West street, New York city. The results confirm those obtained from similar engines in Germany, and are worthy of record as marking a long step forward in the economy of oil engines.

DESCRIPTION OF MOTOR.

The motor has one main cylinder, 10.23 inches diameter and 16.16 inches stroke. The piston, which is exposed to the atmosphere on its under side, drives the main crank by direct connection, and an air-compressing pump, about 3.5 inches diameter and 8.05 inches stroke, through a lever. Two poppet valves in the main cylinder head control the introduction of air from the atmosphere to the main cylinder and the exit of the contents of the main cylinder during exhaust. A smaller poppet valve introduces fuel, which is fed from an oil tank by a small pump. A fourth poppet valve controls the introduction of air from the air receiver for the purpose of starting the motor. The operation is as follows:

The receiver is charged with air at the desired maximum pressure (about 600 pounds per square inch). To start the engine the piston is placed at the top of its stroke. A hand-starting lever

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is set so that all the cams upon the valve shaft are inoperative except the one connected to the starting valve, which then holds the latter open. The oil pump is operated a few strokes by hand, whereby the space around the stem of the starting valve is supplied with oil. On opening a cock by hand, the pressure from the receiver acts upon the piston and starts the latter downward.

At the end of the down-stroke the rotation of the cam shaft has automatically closed the starting valve, and put the three operating valves into regular action. The momentum acquired in the down-stroke carries the piston through an up-stroke, and compresses the contents of the main cylinder to about 520 pounds per square inch, whereby they are heated to a temperature of upwards of 1,000 degrees Fahrenheit. As the piston starts to make another down-stroke by momentum, the fuel valve opens, and the 600 pounds of air pressure in the receiver acting upon the fuel forces it into the heated contents of the cylinder, thereby causing combustion to occur, and power to be developed throughout the second down-stroke, the fuel valve closing at about one-tenth of the stroke of the piston, so that the heat developed is applied with a high degree of expansion. On the next up-stroke the exhaust valve is opened, permitting the cylinder to exhaust itself against the atmosphere. During the next down-stroke of the piston the inlet valve connecting with the atmosphere supplies the cylinder with pure air. This is compressed on the return stroke, and oil again introduced, and thence the operation of the engine proceeds regularly.

The pistons of the main and air cylinders are lubricated automatically from a reservoir.

The revolutions of the engine are governed by a fly-ball governor, which controls the effective length of the stroke of the oil-feeding pump.

The engine was provided with a fly wheel, 6½ feet diameter, weighing about 2,800 pounds. Its total weight, including fly wheel, was about 600 pounds per rated brake H.P., which is about 70 pounds greater than that of a Priestman oil engine, of 7 brake H.P., running 208 revolutions per minute.

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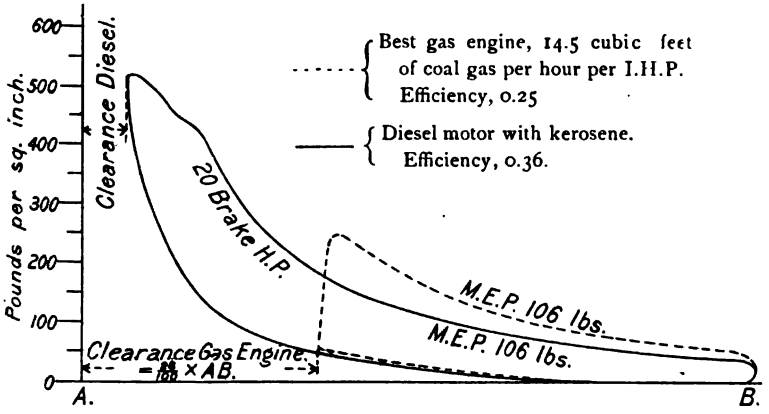
The distinctive thermodynamic features of the engine compared with existing explosive gas and oil engines are:

1. That the cylinder contents during compression consist of air only, so that the compression may cause a pressure at the end of the in-stroke far above that which would cause premature explosion in a gas engine or explosive oil engine.

2. The greater degree of compression confines the contents of the cylinder when combustion occurs to about 0.07 of the cylinder volume, whereas in explosive gas or oil engines they occupy about 0.28 of that volume. (See cut.) Consequently



COMPARISON OF INDICATOR DIAGRAMS FROM A DIESEL MOTOR AND FROM THE BEST GAS ENGINE.

in the Diesel motor the available rate of expansion of the heated contents of the cylinder is several times as great as that of the gas and oil motors, and, therefore, the theoretical proportion of the heat of combustion utilized in work upon the piston is about twenty, twenty-five and thirty-six per cent., respectively, for the best explosive oil engine, gas engine, and Diesel motor.

3. The fuel in the Diesel motor burns gradually in the cylinder during the first one-tenth of the stroke (as does oil which is burned under a steam boiler), without augmenting the pressure above that due to the compression of the contents of the main cylinder by its piston. Consequently the particular proportion of air to fuel necessary to secure explosion is unnecessary.

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The proportion of air to fuel may be anything, provided there is air in excess of that required for combustion. The proportions of this engine permit the excess to be about twenty-five per cent. at full load, and the presence of this excess of air ensures the steady maintenance of perfect combustion, which, together with the relatively small clearance space as compared to that of explosive engines, protects the engine against unreliable acting from fouling of the cylinder under continued action.

RESULTS OF EXPERIMENTS.

Tests were made with ordinary domestic kerosene, and with the various grades of petroleum used as fuel under steam boilers, which covered the operation of the engine for upward of 250 hours, to observe the behavior of the oil and the conditions of the interior of the engine after using each oil. During this time economy tests were made of from one to ten hours' duration, as per the data in accompanying tables. The principal commercial results abstracted from these tables are as follows:

1. With ordinary colorless domestic kerosene, of 120 degrees Fahrenheit flash, 150 degrees Fahrenheit fire test, and 0.784 gravity, at about 187 revolutions per minute, an average of 20.8 brake H.P. was developed, with an oil consumption of 0.534 pound, or 0.082 U. S. gallon per hour per B.H.P.; 13.05 B.H.P., with an oil consumption of 0.586 pound, or 0.0896 U. S. gallon per hour per B.H.P., and 8.78 B.H.P. with an oil consumption of 0.72 pound, or 0.110 U. S. gallon per hour per B.H.P. This shows an efficiency on B.H.P. of 25.8, 23.5 and 19.0 per cent. respectively. The corresponding indicated horse-power efficiencies were 37.7, 41.8 and 41.2 per cent. respectively. These results practically confirm the tests made on an engine rated at 19 B.H.P., at Augsburg, Germany, by Professor Schroeter and other experimenters, which for 17.33 English H.P. showed an oil consumption of 0.54 pound, or 0.0819 U. S. gallon of American kerosene per hour per B.H.P., and for 9.315 English H.P. an oil consumption of 0.63 pound, or 0.0956 U. S. gallon per hour per B.H.P., the efficiencies being as follows:

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	Per cent. on	
	17.33 H.P.	9.315 H.P.
Thermal efficiency on indicated H.P.	34.15	38.18
Thermal efficiency on brake H.P.	25.81	22.12

The same increase in indicated efficiency with reduction of load to one-half, shown by the German tests, is found in the New York tests. The mechanical efficiency, or the per cent. of the indicated power utilized at the brake of the New York motor was not as great as that of the motor tested in Germany—a result which is possibly attributable to the insufficiency of the foundation of the New York motor, which, by permitting excessive vibration, may have caused a waste of power between the cylinder and the brake. The New York motor showed the greater indicated efficiency, however, which is probably due partly to the slight difference of maximum pressure, and partly to the higher temperature of cooling water reducing the jacket waste.

The heat balance for the two cases is as follows:

HEAT BALANCE.

	BRAKE H.P.			
	21.51	8.78	17.33	9.315
	New York.		Augsburg.	
Heat, per cent	37.2	41.2	34.7	38.9
Removed by jacket, per cent	35.4	37.4	40.3	45.1
Remainder, per cent	27.4	21.4	25.0	16.0
Total heat of combustion, per cent	100.0	100.0	100.0	100.0

Examination of the interior of the engine during the use of the kerosene showed that there was no deposit on the surfaces, other than an infinitessimally thin film of lampblack on the cylinder and piston head, which did not increase with time. The bore of the cylinder was clean and polished.

2. With Pratt's fuel oil, which is a dark, straw-colored, clear petroleum, of 200 degrees Fahrenheit flash, 268 degrees Fahrenheit fire test, and 0.852 gravity, considerably used as a steam-boiler fuel, at practically the same revolutions, 20.07 B.H.P. were developed with an oil consumption of 0.613 pound, or 0.0862 U. S. gallon per hour per B.H.P.; and 12.56 B.H.P. with an oil consumption of 0.681 pound, or 0.0958 U. S. gallon, per hour per B.H.P. The operation with this oil was attended with the same insignificant lampblack deposit.

3. With a black, clear, Pennsylvania petroleum, known as

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"Eagle" fuel oil, of 249 degrees Fahrenheit flash, 296 degrees Fahrenheit fire test, and 0.849 gravity, at practically the same speed, 20.75 B.H.P. were developed with an oil consumption of 0.56 pound, or 0.0784 U. S. gallon per hour per B.H.P. This oil left absolutely no deposit in the cylinder.

4. With Lima fuel oil, a black, clear petroleum of 0.856 gravity, at about the same speed, 20.73 B.H.P. were developed with an oil consumption of 0.59 pound, or 0.0826 U. S. gallon, per hour per B.H.P., and 10.77 B.H.P. with an oil consumption of 0.672 pound, or 0.0941 U. S. gallon, per hour per B.H.P. The operation with this oil was attended with no deposit in the cylinder whatever.

5. With California crude oil, a black, clear petroleum of 0.846 gravity, with practically the same revolutions, 20.07 B.H.P. were developed with an oil consumption of 0.626 pound, or 0.0887 U. S. gallon, per hour per B.H.P., and 11.44 B.H.P. with an oil consumption of 0.699 pound, or 0.099 U. S. gallon, per hour per B.H.P. This oil left absolutely no deposit in the cylinder.

With all these oils the engines started instantaneously and operated very steadily. The action of the valve gear is very smooth, and practically noiseless. The combustion occurred with perfect regularity, and was accompanied with no noise other than that due to the pulsation of the floor under the engine. There was also no noise from the exhaust of the engine audible a few feet distant from the chimney into which the exhaust pipe led.

The exhaust gases with all of the oils carried no soot, a piece of white paper being unsoiled by the impingement of the gases against its surface.

No deposit was found in a drum, forming part of the exhaust pipe, after the entire 250 hours of operation of the motor.

The cooling water is shown in the tables to be sixty pounds per B.H.P., with an outflow temperature of 127 degrees Fahrenheit. The engine operates safely, however, with water leaving the jacket at 140 degrees Fahrenheit, which would reduce the water to about fifty pounds, or six gallons per hour per B.H.P. The quantity of water used does not, however, constitute an expense

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TESTS OF THE DIESEL MOTOR.—By Prof. J. E. Denton, M. Am. Soc. M. E.

Kind of oil used	California crude oil.			Eagle crude oil.			Lima crude oil.			
Approximate brake horse power	20 H.P.	20 H.P.	11 H.P.	21 H.P.	11 H.P.	No load.	21 H.P.	15 H.P.	11 H.P.	No load.
Date of test	Aug. 12	Aug. 12	Aug. 12	Aug. 27	Aug. 27	Aug. 27	Aug. 27	Aug. 29	Aug. 27	Aug. 27
Duration, hours	0.99	0.99	1.00	0.76	1.00	0.49	0.96	10.01	1.01	0.50
Pressure in air tank, pounds per square inch	641.1	647.2	628.9	651.7	643.1	620.4	634.6	653.1	650.2	632.5
Temperature of exhaust gases, degrees Fahrenheit	...	...	...	740.+	516.	374.7	740.+	628.3	...	...
Inlet cooling water, degrees Fahrenheit	76.	76.	76.	74.	74.	74.	75.	75.6	75.7	75.
Outlet cooling water, degrees Fahrenheit	118.5	117.5	110.75	127.	123.9	116.5	115.7	126.2	125.	119.
M. E. P. of main cylinder, pounds per sq. in.	104.29	100.32	72.17	110.43	76.14	...	111.87	87.55	77.95	44.03
M. E. P. of air cylinder, pounds per sq. in.	70.62	74.48	78.93	76.135	79.445	75.58	83.31	79.78	83.86	82.75
Max. indicated press., main cylinder, lbs. pr. sq. in.	564.7	557.9	542.4	549.2	529.4	522.4	549.0	537.1	533.7	526.9
Revolutions, per minute	188.4	186.1	186.9	183.65	186.7	188.7	187.1	186.0	186.4	190.1
I.H.P. of main cylinder	32.09	31.32	22.63	34.02	23.85	13.23	35.11	27.32	24.37	14.04
Of air cylinder	2.90	3.10	3.09	3.13	3.32	3.19	3.49	3.33	3.50	3.52
Net	29.19	28.22	19.54	30.89	20.53	10.04	31.62	23.99	20.87	10.52
Brake H.P.	19.64	20.07	11.44	20.76	10.58	...	20.73	15.16	10.77	...
Friction H.P.	9.55	8.15	8.10	10.14	9.95	10.04	10.89	8.83	10.10	10.52
Mechanical efficiency, per cent	67.28	71.12	58.55	67.17	51.54	...	65.56	63.20	51.61	...
Oil consumption: Per hr., per B.H.P. Pounds	0.688	0.626	0.699	0.555	0.691	...	0.590	0.579	0.672	...
Oil consumption: Per hr., per B.H.P. U. S. gal.	0.0975	0.0887	0.0990	0.0784	0.0976	...	0.0826	0.0811	0.0941	...
Per hour per net I.H.P. Pounds	0.463	0.445	0.409	0.373	0.356	0.520	0.387	0.366	0.347	0.487
Per hour per net I.H.P. U. S. gal.	0.0656	0.0630	0.0579	0.0527	0.0503	0.0734	0.0542	0.0513	0.0486	0.0682
Efficiency on brake H.P., per cent	...	...	...	...	...	...	...	...	...	...
Efficiency on net I.H.P., per cent	...	...	...	...	...	...	...	...	...	...
Cooling water, per hour, per brake H.P., pounds	101.7	90.8	170.4	59.9	89.8	...	86.0	71.6	91.9	...
Heat units abstracted pr. hour, pr. B.H.P., B.T.U.	4,322	3,768	5,921	3,175	4,481	...	3,500	3,623	4,531	2,161
Quality of oil: Calorific value,† B.T.U., pr. pound.		19,376			19,742			19,648		
Probable calorific value, (Mahler's bomb)§		...			...			...		
Flash test, degrees Fahrenheit		...			249			90		
Fire test, degrees Fahrenheit		...			296			160		
Specific gravity at 60 degrees Fahrenheit		0.846			0.849			0.856		

† Mahler's bomb. § Corrected for condensed vapor, B. T. U., per pound.

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TESTS OF THE DIESEL MOTOR.—By Prof. J. E. Denton, M. Am. Soc. M. E.

	Ordinary Domestic Kerosene.						Fuel Oil.		
Kind of oil used									
Approximate brake horse power	19 H.P.	21 H.P.	21 H.P.	15 H.P.	13 H.P.	9 H.P.	20 H.P.	13 H.P.	No load.
Date of test	June 30	July 1	July 9	July 8	July 8	July 8	July 29	July 29	July 29
Duration, hours	2.00	4.25	1.966	2.00	0.49	1.50	1.94	2.07	0.81
Pressure in air tank, pounds per square inch	636.6	631.7	643.7	611.7	621.8	618.9	630.1	617.4	623.0
Temperature of exhaust gases, degrees Fahrenheit	740.+	740.+	740.+	673.	601.	511.5	...	...	...
Inlet cooling water, degrees Fahrenheit	73.0	74.0	76.0	77.0	78.0	78.00	74.0	74.6	74.5
Outlet cooling water, degrees Fahrenheit	109.2	110.6	119.9	108.6	128.0	120.6	113.5	104.	98.4
M. E. P. of main cylinder, lbs. per sq. in.	99.565	103.909	108.462	87.612	81.197	66.763	104.65	78 67	39.70
M. E. P. of air cylinder, lbs. per sq. in.	60.00	62.07	61.71	64.89	63.48	63.4	68.96	67.86	66.20
Maximum indicated pressure, main cylinder, lbs. per sq. in.	520.63	521.57	521.08	517.45	510.02	505.5	522.1	515.4	511.4
Revolutions, per minute	187.6	186.6	186.8	191.5	186.5	188.5	184.2	185.7	187.9
I.H.P. of main cylinder	31.33	32.53	33.99	28.14	25.40	21.11	32.34	24.49	12.51
Of air cylinder	2.01	2.07	2.06	2.22	2.145	2.17	2.27	2.25	2.22
Net	29.32	30.46	31.93	25.92	23.255	18.94	30.07	22.24	10.29
Brake H.P.	19.43	20.81	21.51	15.16	13.05	8.78	20.07	12.56	...
Friction H.P.	9.89	9.65	10.42	10.76	10.205	10.16	10.00	9.68	10.29
Mechanical efficiency, per cent	66.27	68.32	67.37	58.49	56.12	46.36	66.74	56.47	...
Oil consumption: Per hour, per B.H.P. — Pounds	0.546	0.534	0.549	0.594	0.586	0.721	0.613	0.681	...
Oil consumption: Per hour, per B.H.P. — U. S. gallon	0.0835	0.0817	0.0839	0.0908	0.0896	0.1102	0.0862	0.0958	...
Per hour per net I.H.P. — Pounds	0.36	0.365	0.370	0.347	0.329	0.334	0.409	0.384	0.427
Per hour per net I.H.P. — U. S. gallon	0.0553	0.0558	0.0566	0.0531	0.0503	0.0511	0.0575	0.0540	0.0601
Efficiency on brake H.P., per cent	25.20	25.77	25.06	23.17	23.48	19.09	...	...	...
Efficiency on net I.H.P., per cent	38.01	37.70	37.19	39.66	41.83	41.20	...	...	...
Cooling water, per hour, per brake H.P., pounds	...	...	82.4	126.8	...	117.8	99.1	154.3	...
Heat units abstracted per hour, per B.H.P., B.T.U.	...	...	3,617	4,007	...	5,018	3,914	4,629	...
Quality of oil: Calorific value,† B.T.U., per pound	20,156						19,980		
Probable calorific value, (Mahler's bomb)‡	18,604						...		
Flash test, degrees Fahrenheit	120						200		
Fire test, degrees Fahrenheit	150						268		
Specific gravity at 60 degrees Fahrenheit	0.784						0.852		

† Mahler's bomb. ‡ Corrected for condensed vapor, B. T. U., per pound.

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item in the use of the motor, as it can be stored in an inexpensive reservoir, or cooling tower, which, once charged, will last indefinitely.

The cost of operation will then be practically confined to the cost of oil, and as the motor shows itself to be able to use oil obtainable at about two cents per gallon, the cost of a B.H.P. may be 0.2 cent per hour, which is slightly less than the cost of the same power from the average triple-expansion steam engine, with coal at $3 per gross ton.

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OFFICIAL REPORT ON THE OPERATION OF ERICSSON'S SURFACE CONDENSER AND EVAPORATOR FOR MARINE ENGINES—1847.

[The following copy of a document in the possession of Mr. Charles H. Haswell is furnished us by that gentleman for publication, and is as interesting to the naval engineer of to-day as the apparatus was novel to those of 1847.]

"NEW YORK, *October 31st, 1847.*

"SIR: In acceptance of your invitation of the 17th ultimo, we, the undersigned, had the honor to meet together in the City of New York, with the view of testing and reporting upon an apparatus invented by Captain John Ericsson, for the purpose of supplying the boilers of marine steam engines with a continuous supply of fresh water, and applied by him under your direction in the U. S. Revenue Steamer *Legaré.*

"We have now respectfully to report that, on the 23d ultimo, we embarked in the *Legaré* at 12 M., proceeded to sea, and remained on board till the following morning. During this time the boiler was in operation fifteen hours, and we had ample opportunity of examining the means employed for supplying it with water and the results produced.

"By the ordinary method of condensing steam in marine navigation, boilers are supplied with the *water of condensation*, composed of the steam that is withdrawn from the boiler and the necessary quantity of salt water required for its condensation. Hence, a boiler in operation is constantly parting with steam (fresh water) and receiving salt water in exchange. The effect of this operation, uninfluenced by a correction, would be that in a few hours a degree of saturation of the water in the boiler would be reached that would precipitate upon the plates of the furnaces and flues a scale of sufficient thickness to arrest the passage of the heat to the surrounding water and cause the

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destruction of the plates by exposing them to a temperature destructive of their tenacity. The correction in use is the removal of the water as it approaches saturation, and is effected by *blowing*, or *pumping off*.

"In the operation of either of these methods, it is apparent that there is a loss of the heat that has been imparted to the water blown or pumped off; that neglect to open or shut the blow-off cock, or in the admission of the required supply of water, involves the duration of the boiler, and may, as it frequently does, involve the lives of the passengers and crew and the safety of the vessel. Even when all practicable attention is given to blowing-off, salt scale will be deposited in long voyages, particularly in the middle latitudes, and accumulate to an extent that renders its removal imperatively necessary. This is at all times a difficult, and even under the most favorable circumstances an imperfect, operation, and when this deposit coats the surfaces of the flues the consumption of fuel is increased to an extent unsuited to the economy of mercantile enterprise, and to the duration of operation requisite for naval purposes.

"This evil may be avoided by furnishing the boilers with a full supply of fresh water, and as the weight could not be accommodated, nor the space spared in a vessel for an instrument and its fuel for the sole purpose of distilling the quantity required, it is obvious that the steam furnished by a boiler must be returned to it, after being condensed by the radiation of its heat to cold surfaces, and not by the admixture of water. This method was *proposed* by James Watt, so early as the year 1776, and has been effected to some extent by an instrument invented by Mr. Samuel Hall, of England, and applied to the engines of many steam vessels, in some of which, notwithstanding its imperfections, it is yet used. It has failed, however, to answer the full purposes desired and anticipated.

"In the arrangement of Mr. Hall, a great number of thin metal tubes, from one-half to three-fourths of an inch in diameter, were placed *vertically* in a condenser and exposed to a current of cold water from the sea, and into which the steam from the cylinder was admitted, for the abstraction of its heat

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by the radiation of it to the water without the tubes. Now, it is evident that by this arrangement the condensed steam would run down the inner surface of the tubes, in its passage presenting a non-conducting lining to them, and in its collection at their bottom an obstacle to the current of the steam and a diminution of the effective radiating surface.

"With this method of condensation, it will be perceived that this instrument provides alone for returning to the boiler the water that has passed through the engine as steam. It follows, then, that all escapes of steam from the boiler or engine or water leaks from the boiler, pipes, etc., must be replaced by distillation, at an expense of fuel, directly as the evaporation. Further, continued use of this instrument exhibited an oleaginous deposit upon the inner surface of the tubes from the use of oil and tallow in the steam cylinder and on the valve faces, which, acting as a non-conductor, materially obstructed the condensation of the steam.

"The apparatus of Captain Ericsson was designed to obviate the difficulties and deficiencies developed in that of Mr. Hall, and is composed of two distinct instruments, a condenser and an evaporator; the first for the purpose of condensation, and the latter for a supply of fresh water to provide for any losses of steam or water from the boiler by escapes, leaks, gauge vents, &c., &c.

"The condenser is a cylindrical vessel, set at a slight inclination from a horizontal line, containing the requisite extent of radiating surface in metal tubes of *two inches* bore, with an open space at each end. By this arrangement there is free space for the current of steam to pass, and for the condensed steam to run down the lower side of the tubes, without presenting a lining of water to intercept radiation or an obstruction to the course of the steam. Connected with this is a pump, by which water from the sea is drawn in and forced through the spaces between the tubes and the inner surface of the shell of the condenser. Thus the latent heat of the steam is absorbed by contact with the tubes, and condensation is effected for the double purpose of affording a vacuum for the engine and of restoring fresh water

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to the boiler, for continuous evaporation and condensation, to meet the requirements of the engine.

"The evaporator, as constructed, is a parallelopipedon, with a semi-cylindrical top and bottom, the lower portion of which is occupied by a number of tubes similar to those in the condenser, which communicate with a valve at each end of the steam cylinder, worked by the engine; around these tubes, and for some distance above them, water from the sea is admitted for the purpose of being evaporated, and the space above this water is open to the condenser, and consequently *in vacuo.* This instrument being designed to furnish fresh water to replace that which may be lost, its operation is resorted to only as occasion may require, and is effected in the following manner: When the piston is near the termination of its stroke, the valve referred to opens (above or below, as the case may be), and closes when the piston begins its return stroke; by this arrangement steam is withdrawn from the engine that has very nearly performed its full expansive effect, and passing into the tubes of the evaporator its heat is absorbed by the water surrounding them, and as this water is *in vacuo* it readily boils at a low temperature, and its vapor being led to the tubes in the condenser, it is condensed with the steam from the cylinder, and is supplied to the boiler.

"Upon the experimental trial to which you were pleased to request our attention, all practicable arrangements for correct observations were entered into; and with a view to acquire full and progressive notes of the operations of the apparatus, the observations of the various points were confided to special committees, which, upon the conclusion of the trial, reported full notes for furnishing the following, viz:

"The boiler was filled with fresh water from above the opening of the blow-off cock; below this, salt water had been left, from an impression of its effect being too inconsiderable to authorize its removal.

"At the commencement of the operation of the engine, the water in the boiler as indicated by a saline hydrometer, when at a temperature of 150 degrees Fahrenheit, was $\cdot\frac{63}{32}$.*

* $\frac{13}{32}$ being the point of saturation of water when at a temperature of 200 degrees.

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"The highest temperature of the *feed water* observed was 158 degrees Fahrenheit.

"The lowest 132 degrees, and the average 150 degrees.

"The highest *vacuum* observed was from sixteen to eighteen inches.

"The lowest from eleven to fifteen, and the average was from twelve to fifteen inches.

"The highest *steam pressure* was fifty-four pounds mercurial gauge.

"The lowest was twenty pounds, and the average was 48.6 pounds.

"The highest number of *revolutions* was forty-seven per minute.

"The lowest number was thirty, and the average 42.3.

"The point of cutting off was at three-eighths of the stroke.

"The temperature of the sea water was fifty-seven degrees.

"Duration of *operation* of the engine and boiler, fourteen hours and twenty minutes. Time during which steam was raised, twenty hours.

DIMENSIONS OF ENGINE, &c.

"*Cylinder.*—Thirty-six inches in diameter, with a stroke of piston of thirty-two inches.

"*Boiler.*—1,400 square feet of heating surface.

"*Condenser.*—637 square feet of radiating surface.

"*Evaporator.*—100 square feet of heating surface.

"Upon the arrest of the test, the freshness of the water was again tested, and when at a temperature of 150 degrees by a different thermometer than that used at the first operation (it having been broken in the interim) the hydrometer indicated $\cdot\frac{75}{32}$; whether this difference in the indications is to be attributed to a change in the density of the water or to a difference in the thermometers, they being of different manufactures, we are unable to decide; fortunately the difference is quite inconsiderable, and is not regarded as deserving of further consideration.

"So soon as the temperature of the condenser was reduced to a degree that rendered an examination of it practicable, one of its heads was removed in our presence, and the tubes, when examined, were entirely free from any deposits or incrustation

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upon their surfaces, and the opinion is entertained, that at a temperature of feed water commensurate with economy of fuel, any difficulty from the deposit of oleaginous matter in this instrument is not to be apprehended.

"Regarding the particular performances of the condenser and evaporator, it appeared that Captain Ericsson had relied too confidently on a general current of the cold water through the former instrument, whereas the current was quite partial, being but directly through its narrowest part, the sides of it; hence, the upper portion of it was almost inoperative, this feature was clearly developed by the application of a hand along the surface —while the effect of it was apparent in the moderate condensation indicated by an attached mercurial gauge.

"Of the evaporator, its capacity was clearly shown, in the facility with which the level of the water in the boiler could be raised through the space between two gauge cocks and by a resort to its operation, not being necessary for more than one-tenth of the time.

"Immediately after the close of this trial, measures were taken to effect a diffused operation of the cold water, and as diaphragms could not be introduced between the tubes to alter the current of the water, without incurring an impracticable delay, the expedient of causing the steam to circulate through the tubes was resorted to, and was effected by the application of diaphragms in the open space at each end of the tubes. Upon the completion of this, a further trial was had on Friday, the first instant, when several observations furnished the following:

Pressure of steam,	50	pounds mercurial gauge.
Revolutions,	47	per minute.
Vacuum,	20.5	inches.
Temperature of feed water,	150°	Fahrenheit.
Temperature of sea water,	62°	Fahrenheit.

Compared with the ordinary method of condensation, the value of the method observed is determined by an investigation and consideration of the following points, viz: Evaporation, pressures, consumption of fuel, safety and duration of the boiler.

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1.—EVAPORATION. *Ordinary method.*

Temperature of feed water, 100° Fahrenheit.

Temperature of sensible and latent heats of steam	1,192°
Deduct temperature of feed water	100°
Heat to be added	1,092°

New method.

Temperature of feed water, 150° Fahrenheit.

Temperature of sensible and latent heats	1,192°
Deduct temperature of feed water	150°
Heat to be added	1,042°

Then $\frac{1042}{1092} = \frac{.954}{1.}$ which represents a gain in the evaporating temperature in the new method of 4.56 per cent.

2.—PRESSURES. *Ordinary method.*

Pressure of steam—mercurial gauge	50 lbs.
Vacuum, 28 inches	= 13.7 lbs.
	63.7 lbs.

Cut-off at three-eighths of the stroke.

Effective pressure on the piston	= 47 lbs.

New method.

Pressure of steam	50 lbs.
Vacuum, 20.5 inches	= 10 lbs.
	60 lbs.
Effective pressure on the piston	44.5 lbs.

Then $\frac{47}{44.5} = \frac{1.05}{1.}$ which represents a loss in pressure by the new method of 5 per cent.

3. CONSUMPTION OF FUEL. *Ordinary method.*

In the Gulf of Mexico and between the Tropics, it is necessary to blow off, when a hydrometer constructed similar to the one already referred to, indicates $\frac{2}{32}$; in the Northern and Southern Atlantic and Pacific Oceans, when it indicates $\frac{2.5}{32}$. Hence, $\frac{2. + 2.5}{2} = 2.25$ the average point for blowing off.

As the average degree of saturation of feed water is $\frac{.75}{32}$; the

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quantity of water blown off compared to that fed to a boiler is as 75 to 2.25, which is in the proportion of 1 to 3.

Temperature of the water blown off at the pressure and degree of saturation given	290°
Deduct temperature of feed water	100°
Temperature lost by blowing off	190°
As the heat to be added for the purpose of evaporation is 1092°—	
$1092 \times 3 \infty 1$, the proportion of feed water evaporated =	2184°
And $190 \times 3 \infty 2$ the proportion of feed water blown off =	190°
The heat absorbed, is	2374°
Then $\frac{190}{2374} = \frac{.08}{1.00}$ which represents the loss of heat by blowing off in the ordinary method of	8. per cent.

SUMMARY OF RESULTS.

Gain by evaporation	4.56	per cent.
Do. do. consumption of fuel	8.	"
	12.56	"
Loss by pressure	5.	"
Total	7.56	"

Which is a saving in the expenditure of heat, affording a like economy in the consumption of fuel and altogether independent of the loss of heat, by the presence of scale in a boiler, when salt water is used, and from leaks incurred by the oxidizing effects of salt water.

With the *ordinary method*, the level of the water in a boiler is constantly varying from one or both of the following causes, viz: the quantity of the water blown off, or the particular extent of opening of the feed valve; while the effective operation of the feed pump and neglect of the blow-off valve, involves the burning, or an explosion of the boiler.

With the *new method*, these operations are set aside, thus blowing off is unnecessary and the supply to the boiler being first obtained from it, the transit being immediate and the communication incapable of restriction (for if the condensed water was not taken off by the feed pump, the condenser would choke and become inoperative), there can be no decrease in the level of the water, other than that arising from leaks of water and steam.

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Further, the use of fresh water in a boiler will extend the term of its duration from three and five years to seven and nine.

With a further modification of the condenser, establishing a more diffused current of the cold water, it is evident that a full vacuum may be obtained, as the practicability of attaining this end by external condensation, has long since been developed, and with a less proportion of radiating surface than is exposed in the instrument referred to. From the analysis however here given regarding pressures and temperatures, it would appear that a full vacuum, with corresponding reduction of the temperature of the feed water is not authorized, and as such departure from the hitherto practice, furnishes the temperature necessary to prevent any oleaginous deposit upon the surface of the tubes of the condenser, practice and utility are in desired harmony.

A very effective and economical element in steam navigation arises with the operation of this new method, from the absence of scale in the boiler, the presence of which is unavoidable where salt water is used, and to avoid the formation of it as far as practicable, other than a low temperature and corresponding pressure are precluded by the waste of fuel and injury to the boiler consequent upon the existence of this scale, acting as a new conductor of the heat to the water—whereas, with the use of fresh water, higher pressures can be worked and economy of fuel attained in an increased expansion of the steam.

Reviewing the facts herein presented, we are of the opinion that the operation of the apparatus of Captain Ericsson, as far as developed, was eminently successful, and that, with the modification of the condenser suggested, a higher degree of vacuum can be readily obtained. In view of the very great importance of the successful introduction of this method of condensation in the merchant and naval services, we recommend to your consideration the propriety of sending the *Legaré* on a distant cruise, for the purpose of developing the advantages of the apparatus by continued and extended use.

Apprised of the ready attention you have given to this important subject, and the zealous interest you have manifested in its development, we cannot but congratulate ourselves and the pro-

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fession with which we are connected, that you have seen fit to test this improvement by the construction of the apparatus on which we have been called to report. Such encouragement identifies in the merits of success the patron with the improvement, and is honorable to yourself no less than the nation in whose service you have bestowed it.

We have the honor to be, very respectfully,

Your obedient servants,

CHAS. H. HASWELL, *Engineer-in-Chief U. S. N.*
JAS. J. MAPES, *New York.*
LEWIS TAWS, *Philadelphia.*
JAMES MCFARLAN, *Union Ferry Co., N. Y.*
J. H. TOWNE, *Philadelphia.*
WM. SEWELL, JR., } *Chief Engineers U. S. N.*
WM. W. W. WOOD, }

To the Honorable
ROBERT J. WALKER,
Secretary of the Treasury,
Washington, D. C.

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THE VALUATION OF COALS.*

By N. W. Lord.†

[Reprinted from "Engineering News," Feb. 16, 1899.]

The application of chemical analysis to the economic valuation of coals, so that it can furnish a guide to the consumer in the purchase of fuel, is hardly to be considered as in a satisfactory state of development. Many hundreds of "proximate" analyses of the various coals have been published by the State Geological surveys, as well as by others, and several attempts have been made to generalize these results, so as to arrive at workable formulas by which given samples of coal could be valued and their actual performance predicted, but the results, so far, do not seem to have met any general acceptance.

The subject is one to which the writer has had to give considerable attention, and it is the object of the present paper to present and discuss a number of unpublished tests and analytical results which have been collected from various sources.

The starting point in determining the value of any fuel for any purpose is, of course, its calorific power or "absolute heating power." This has been for so long a commonplace that it seems singular that only recently has the determination of this fundamental constant been required of chemists by the mechanical engineers. The calculation of the heating power from the ultimate analysis was so long considerd inaccurate to a degree precluding its use in valuing fuels that possibly on this account ultimate analyses of coals were rarely made in this country. The difficulties in the way of an accurate ultimate analysis are also

* A paper presented in Section C, Chemistry, of the American Association for the Advancement of Science, Boston meeting, Aug., 1898.

† Professor of Metallurgy in the Ohio State University, Columbus, O.

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well known. At any rate it is a fact that many such results from reliable sources are not to be obtained for American coals.

In a paper by the writer, in connection with Mr. F. Haas, published in 1897 (Trans. Am. Inst. Mining Engineers, and Eng. News, March 25, 1897), there were a given number of ultimate analyses and calorimeter determinations which tended to show that the calorific value of the coal from a given bed was nearly constant over considerable areas of the seam, provided the observed value on any sample was reduced to an ash, sulphur and moisture-free basis.

Since the publication of the results referred to the Jackson coal, another prominent Ohio seam, has been investigated. This furnishes a large amount of first rate coal to the Ohio markets. The bed covers a considerable portion of Jackson county. Samples were obtained from mines opened in the eastern, western, northern, southern and central portions of the field. The samples were carefully taken by Mr. Laviers, engineer of the Superior Coal Company, and a former student of the writer's. The samples were from large amounts, and were intended to represent the average composition of the coal as mined at the selected points. The ultimate analyses and the calorimeter determinations were then made in the laboratory of the department of metallurgy by my assistant, Mr. Haas. The results are given in Table I.

The results shown appear fully to support the conclusions drawn in the former paper, that the heating value of the coal is practically constant throughout the bed. The failure of the last two samples to show close correspondence between the calculated values by Dulong's formula and the calorimeter results is contrary to our experience with other coals. These last two analyses are the average of duplicates which do not agree very satisfactorily, and, therefore, the results are a little open to question, as I fear some carbon may have escaped combustion. The other analyses given in the table are the average of very closely agreeing duplicates.

If the conclusion as to the comparative constancy of the heating value of the coal in any given seam is correct, then the

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TABLE I.—ANALYSES OF JACKSON, OHIO, COAL.

Sample.	Carbon.	Hydrogen.	Oxygen.	Nitrogen.	Sulphur.	Ash.	Moisture.	Volatile combustible.	Fixed carbon.	Calorimeter result.	Calorific power calculated from ultimate analysis.	Difference, per cent.	Calorific power calculated from *H*.	Difference, per cent.
1 Center	70.05	5.43	17.09	1.49	1.84	4.10	8.26	35.15	52.49	6,854	6,835	— .3	6,844	— .1
3 North	71.20	5.50	17.71	1.45	0.76	3.38	8.45	34.09	54.09	6,937	6,890	— .7	6,949	+ .2
4 South	70.12	5.49	16.96	1.50	1.45	4.48	7.02	37.66	50.82	6,956	6,860	—1.3	6,935	— .3
5 West	71.42	5.37	19.49	1.43	0.64	1.65	8.65	34.30	55.40	6,981	6,795	—2.7	7,077	+1.4
6 East	70.79	5.55	18.60	1.46	0.95	2.65	8.50	37.75	51.10	7,069	6,854	—3.1	6,992	—1.1
Average	70.72	5.47	17.97	1.47	1.13	3.25	8.17	35.79	52.78	6,953	...	...	...	...

$$H = \frac{6,934}{0.8745} = 7,929.$$

NOTE.—*H* equals the average of the calorimeter results minus 22.5 times the average per cent. of sulphur, the remainder multiplied by 100 and divided by 100 minus the sum of the average percentages of ash, sulphur and moisture. It stands for the average heating power of the combustible portion of the coal less the heat due to the combustion of the sulphur. The calculation of the heating power of any sample from a seam, when *H* is known, consists in multiplying *H* by 100 minus the ash, moisture and sulphur (in per cents.), dividing by 100 and adding 22.5 times the per cent. of sulphur.

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determination of the heating power for any particular sample from the seam becomes a simple matter, if the ash, sulphur and moisture in the sample be known, and the seam constant for the kind of coal be known.

The substitution of complete sets of determinations of the ultimate composition and heating values of the coals in the different seams of a State for the present mass of proximate analyses of scattered samples would do much to clear the subject of coal valuations of its uncertainties.

The main point at issue, however, is the relation between the calorific power of the fuel and its industrial value and how far this can be determined by chemical methods. With a view to getting more light on the subject, the writer has collected a considerable number of results of actual boiler tests made on the coals of the seams which have been examined in the laboratory of the department. These results have been furnished the writer by various persons in private communications. For commercial reasons the names of these furnishing the results cannot usually be given, but all the results are from large consumers of coal, thoroughly competent to judge of the care with which these tests were made. A number of the results are from tests made by Professor Hitchcock, of the Department of Mechanical Engineering of the Ohio State University, who has kindly furnished me with the evaporation figures he obtained. In the tests made by Professor Hitchcock most of the chemical and calorimeter work was done by Mr. Haas, my assistant, in the department of metallurgy, to whose industry, accuracy and enthusiasm I am indebted for many of the results herewith presented.

The accompanying table gives the evaporation tests, together with the refuse or ashes, determined practically from the weights of the material collected in the ash pits, as reported by those furnishing the tests. The percentage of unburned coal as given in the table is estimated in most cases by proportion from the percentage of ash found in the ash-pit refuse and percentage of ash in the analysis of the coal. In other cases it is calculated by deducting from the per cent. of ash-pit refuse the per cent. of ash found in the analysis of the coal.

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All the analyses were made in the laboratories of the department, and of samples taken from the coal used in the boiler tests.

The evaporation results given in Table II were obtained from different types of boilers and grates and by different observers,

TABLE II.—BOILER TESTS WITH VARIOUS COALS.

No.	Water evaporated from and at 212° F.	Refuse.	Ash by analysis.	Coal unburned.	Moisture.	Calorific power.	Kind of boiler.
	Pr. pound.	*Pr. ct.*	*Pr. ct.*	*Pr. ct.*	*Pr. ct.*	*h. u.*	
Pocahontas Coal.							
1	9.94	11.8	7.92	3.9	0.77	7,988	Water tube, *s.*
2	9.29	5.94	6.99	3.0	0.61	8,080	Water tube, *h.*
3	8.37	8.26	5.63	2.5	0.63	8,185	Water tube, *h.*
4	8.04	8.88	5.81	4.6	...	...	Multitubular.
5	7.73	14.61	5.81	5.7	...	...	Multitubular.
6	10.66	...	3.83	0.2	...	8,409	Water tube, *s.*
7	10.89	...	6.05	0.3	...	...	Water tube, *s.*
Average	9.28	...	6.01	2.9	...	8,140	
Hocking Coal.							
8	7.72	13.83	10.59	6.7	6.50	6,499	Water tube, *s.*
9	6.23	6.97	9.10	3.2	6.45	6,603	Water tube, *h.*
10	6.06	6.38	...	...	6.72	6,882	Water tube, *h.*
11	6.52	6.38	8.50	2.3	6.40	6,610	Water tube, *h.*
12	7.34	9.76	7.48	3.3	...	...	Multitubular.
13	7.15	11.32	7.48	3.3	...	...	Multitubular.
14	7.72	4.36	4.32	2.7	...	...	Multitubular.
15	8.72	...	9.37	0.7	6.68	6,616	Water tube, *h.*
16	8.00	...	12.85	0.9	6.00	6,482	Water tube, *h.*
17	7.45	...	16.95	8.5	7.55	6,089	Water tube, *s.*
18	6.52	...	12.95	5.0	6.20	6,454	Water tube, *s.*
19	6.22	...	12.45	4.1	6.10	6,569	Water tube, *s.*
20	6.78	...	14.85	8.5	6.13	6,458	Water tube, *s.*
Average	7.11	...	10.55	4.1	...	6,526	
Thacker Coal.							
21	9.37	12.77	7.25	7.10	1.27	7,789	Water tube, *s.*
22	8.79	12.15	...	...	...	...	Water tube, *s.*
23	7.55	5.68	6.50	2.3	1.40	7,768	Water tube, *h.*
24	7.39	6.44	7.50	2.5	1.60	7,738	Water tube, *h.*
25	8.59	...	7.87	7.8	1.56	7,587	Water tube, *s.*
Average	8.36	...	7.28	4.9	...	7,720	

s = mechanical stoker; *h* = hand-fired.

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Upper Freeport Coal.

No.	Water evaporated from and at 212° F.	Refuse.	Ash by analysis.	Coal unburned.	Calorimeter value.	Kind of boiler.
	Pr. pound.	*Pr. ct.*		*Pr. ct.*		
26	7.27	17.34	11.89	5.4	...	Stationary.
27	7.41	16.48	9.58	6.9	...	Stationary.
28	7.62	14.30	7.82	6.5	...	Stationary.
29	7.65	11.54	9.17	2.3	...	Stationary.
30	7.84	12.70	7.66	5.0	...	Stationary.
31	7.42	14.08	9.42	4.7	...	Stationary.
Average	7.53	...	9.26	5.1	7,326	
32	6.45	...	9.10	...	7,326	Locomotive.
33	7.11	...	8.10	...	...	Locomotive.
34	6.54	...	10.45	...	...	Locomotive.
35	6.72	...	8.70	...	...	Locomotive.
36	6.23	...	8.25	...	...	Locomotive.
Average	6.61	...	8.92	...	7,212	

Darlington Coal, Pennsylvania.

37	7.26	14.39	4.35	10.0	...	Stationary.
38	7.34	14.16	8.75	5.4	...	Stationary.
39	7.62	12.22	4.95	7.3	...	Stationary.
40	7.51	14.98	6.65	8.3	...	Stationary.
Average	7.43	...	6.18	7.7	7,652	
41	7.15	...	8.70	...	...	Locomotive.
42	6.47	...	8.80	...	...	Locomotive.
43	6.04	...	8.05	...	...	Locomotive.
Average	6.55	...	8.52	...	7,283	

Pittsburg Coal.

44	8.00	11.52	5.93	5.6	...	Stationary.
45	8.43	11.82	7.95	3.9	...	Stationary.
46	7.89	11.60	6.08	5.5	...	Stationary.
47	7.83	12.55	9.25	3.3	...	Stationary.
48	7.88	11.57	8.86	2.7	...	Stationary.
Average	8.01	...	8.01	4.2	7,596	
49	8.12	...	9.05	...	...	Locomotive.
50	7.66	...	9.05	...	...	Locomotive.
Average	7.89	...	9.05	...	7,374	

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and hence can not be taken as giving the comparative values of the different samples of coal tested, but in the aggregate they represent a varied experience in the use of coals of the same character for the purpose of steam raising.

The evaporation figure given by a single test in any given boiler and furnace is, of course, dependent upon a number of factors, only one of which is the absolute heating power of the coal. This will account for the wide variation shown in the results obtained from coals of nearly the same heating power and of the same seam. Thus Hocking coal gives evaporation varying from 6.22 up to 8.72, the corresponding calorific values being 6,616 and 6,569, a difference of evaporation of nearly 30 per cent., and a difference in calorific power of less than 1 per cent. These two tests were made in Columbus, and I am able to present the complete "heat balance" as computed for the test by Mr. Haas from his observations of the flue temperature, composition of the flue gas, analysis of refuse, etc. The tests which gave 8.72 pounds evaporated was made on "run of mine" coal in a hand-fired furnace. The flue gas was analyzed every thirty minutes, and the flue temperature read at the same time. The coal and refuse were carefully sampled and analyzed. The average flue temperature over that of the outside air was 244 degrees centigrade, the average excess of air in the flue gas 71 per cent. of that required for complete combustion. The heat distribution was as follows:

	Calories.	Per cent.
In products of combustion	563	8.5
In excess of air in flue gas	348	5.3
In latent heat in flue gas	276	4.2
In unburned coal	47	0.7
In evaporation	4,683	70.8
In radiation, etc. (by difference)	699	10.5
Calorimeter test (by bomb)	6,616	100.

The test which gave 6.22 pounds evaporation was made on "pea and slack" coal fired by a mechanical stoker. The flue temperature in excess of the external air was 274 degrees centigrade, and the average air excess in the flue gas was 281 per

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cent. The gas analyses were made every fifteen minutes by the Orsat apparatus. The heat distribution was as follows:

	Calories.	Per cent.
In products of combustion	633	9.6
In excess of air in flue gas	1,542	23.5
In latent heat in flue gas	2,259	3.9
In unburned coal	204	3.1
In evaporation	3,340	50.8
In radiation, etc. (by difference)	591	9.1
Calorimeter test (by bomb)	6,560	100.

Another sample of coal in the same boiler as the last test gave 6.52 pounds evaporated. Test made on pea and slack Hocking coal. Average flue temperature over external air, 265 degrees centigrade; average air excess, 205 per cent:

	Calories.	Per cent.
In products of combustion	604	9.3
In excess of air in flue gas	1,069	16.5
In latent heat in flue gas	265	4.1
In unburned coal	308	4.8
In evaporation	3,501	54.2
In radiation, etc. (by difference)	707	10.9
Calorimeter test (by bomb)	6,454	100.

Samples like the above could be given of numerous other tests. The facts illustrated are, however, well known to all who have worked in connection with boiler tests. To the boiler maker or user the chemical analysis of the coal and its calorific value are of vital importance, as they enable him to construct just such a heat balance as above quoted, and to judge from this the performance of the boiler. The recent report of the committee on boiler tests to the Society of Mechanical Engineers dwells fully on the importance of this work.

Only the ultimate analysis of the coal will serve the purpose. Fortunately the ultimate analysis calculated from the average analysis of the seam can be used with little error if applied to the special coal samples with due correction for moisture, ash and sulphur in the sample tested. Boiler tests are expensive and demand mechanical engineers as well as chemists. The simple

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evaporation test without the heat balance gives no proper valuation of the single coal sample itself, as the figures quoted clearly show. How far can chemical analysis alone be used in predicting the boiler test, as it were? This resolves itself into an examination of how far the well-known formulas and methods for computing heating effects and losses can be depended upon. The consideration of any heat balance such as those quoted shows that besides the useful or available portion of the heat, there are two classes of heat losses. First, those dependent on the coal, and second, those dependent upon the grate, the style and condition of the boiler and the skill of the fireman. The second of these is not a matter determinable by the chemist from the analysis of the coal. By the general principle of averages, losses of this kind should tend to equalize themselves when a considerable number of results on the same coal are united, thus by taking the average of a series of evaporation tests a result should be obtained which would give a difference between the heat used in evaporation and the total heat devoloped that could be divided into two parts, one varying with the kind of coal, and the other more or less constant and independent of the kind of coal. This latter loss could be included in the valuation of the coal in one of two ways, either by subtracting a value for it as found from the average coal burned or by subtracting the value for it found in what might be considered the best tests. It would seem that the latter plan would be the more desirable, as it would tend to value the coal at an attainable figure, and yet one which would serve as a guide to the user and furnish a check on the performance of his grate and boiler. If a standard set of conditions in this regard be assumed it is obvious that all coals would be graded by them fairly.

The losses dependent upon the composition and character of the coal can be easily computed by well-known formulas. They comprise the heat latent in the products of combustion in water vapor, and the sensible heat in the product of combustion. The heat in the air excess, if the latter is measured in percentages of the air required to burn the coal, is to a certain extent dependent upon the composition of the coal for its computation and

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expression. One loss, varying with the coal as well as the grates, will be the percentage of unburned coal, which more or less depends on the friability, coking power and mechanical condition of the coal. The relation of this to the mode of combustion is, however, much closer than it is to the character of the coal, as is easily seen by reference to the results quoted in the table. The results for Pittsburg coal and for the Hocking coal are in the averages about the same, while the variation in each coal, according to the grate used, is very large. One of these is, as is well known, a strongly coking coal, and the other a typically non-coking coal. This factor in the valuation of the coal is best estimated from an analysis of the refuse from grates burning the coal. A simple estimation of the ash or non-combustible portion of the refuse is all that is needed. This assumes that the unburned portion is coal and not coke, which is probably only partially true. The error caused by assuming it to be pure carbon would in any case be but trifling. Numerous analyses have been made in our laboratory, which show that the unburned coal in the refuse is to a considerable extent uncoked. For example:

REFUSE FROM ASH PIT.

	Thacker coal.	Pocahontas.	Hocking.
Moisture	0.15	0.40	0.83
Volatile	3.37	4.50	7.25
Fixed carbon	29.96	32.50	33.27
Ash	64.00	62.60	58.65

The figures for the Thacker coal are the average of two analyses. It will be seen that the volatile matter is considerable, though not equal to what it would be in the coals. The radiation and other losses determined by difference in the boiler tests are somewhat variable. The writer has been in the habit of assuming this amount at 10 per cent. of the calorific power of the coal. This assumption is, of course, arbitrary, but a number of boiler tests made at the University give results approximating quite closely to this figure. If this correction be applied to the common formulas used in heat calculations, we would have for the relative practical heating value of the coal, or what might be called the "available heating power," the following:

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"Available heating power" $= \frac{9}{10}$ calorific power—latent heat—T (into water equivalent of products of combustion added to water equivalent of excess of air).

The evaporating power would be equal to the available heating power multiplied by 1 minus the fraction of unburned coal, and divided by 537. The air excess is easily determined from the flue gas analysis. If this analysis is expressed in parts by weight, then the ratio of the air excess, that is, the air present in the gas, divided by the air used in the combustion of the fuel almost exactly equals $\frac{O}{\frac{3}{10} N - O}$. Let A stand for the ratio of the air excess and insert the values of the specific heats, and let C H S and O stand for carbon, hydrogen, sulphur and oxygen, shown in the ultimate analysis of the coal, and we have the following formula.

Available Heat $= 0.9$ calorific power $- 9$ H $\times$ 589. $-$ T° carbon $(11/3 \times 0.217 + 8/3 \times 3.33 \times 0.244 + 8/3$ A $\times 4.33 \times 0.237) -$ T° H $\times 9 \times 0.48 -$ T° (H $- 1/8$ O) $(8 \times 3.33 \times 0.244 + 8 \times 4.33 \times 0.237$ A) $-$ T° sulph. $\times (2 \times 0.154 + 3.33 \times 0.244 + 4.33 \times 0.237$ A). This reduces to

Available Heat $= 0.9$ calorific power $- 5{,}301$ H $-$ T° C $(2.963 + 2.738$ A) $-$ T° H $\times 4.32 -$ T° (H $- 1/8$ O) $(6.498 + 8.209$ A) $-$ T° S $(1.121 + 1.027$ A).

Of course this is only text-book work, but where the values of A and T are determined by experiment and the value of the coal unburned by analysis of the refuse, the above expression will give the evaporation shown by the coal within a reasonably close figure, as the writer has verified repeatedly. When the C O forms a noticeable percentage of the gas the results will be unreliable. This condition is on the whole uncommon, and is usually associated with a small air excess, and is obviously wasteful of coal. In the records of many flue gas analyses in the department of metallurgy, few show more than fractions of a per cent. of C O present. The grading of coals generally by any such formula will, however, depend upon the assumption of standard values for A and T. In order to apply it to the boiler tests given in the table, I have assumed, for purpose of comparison, A equal to 1 (or 100 per cent.

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of air in excess of that required to burn the coal), and T equal to 200° C., as representing a fairly attainable figure in good practice. If these conditions be introduced into the above formula it takes the following form, provided the sulphur is omitted as unimportant, in such a formula only intended for practical results:

$$\text{Evaporating power} = \frac{1}{537} - (9/10 \text{ cal. P} - 9{,}106 \text{ H} - 1{,}140 \text{ C} + 377 \text{ Ox}).$$

Applying this to the average results on the coals tested, the average composition of the Pocahontas coal, as shown by analyses previously published, is as follows: C, 84.87; H, 4.29; O, 3.51; N, 0.85; S, 0.59; Ash, 5.89.

By the assumed formula this would give an evaporating power of 11.2, assuming the coal all burned. The average unburned coal of the test is 2.9 per cent. Correcting for this, there remains an evaporative efficiency under the assumed conditions of 10.9 pounds. The average of the tests is 9.28. The best test is 10.89.

The average composition of the Hocking coal as given in the paper previously quoted is: C, 68.03; H, 5.29; O, 15.64; N, 1.44; S, 1.59; Ash, 8.00. The formula gives for its evaporative value under standard conditions, 8.9 pounds, or allowing for the average unburned coal, 8.6 pounds. The best result of the test is 8.72. The average is 7.11. In the same way the Thacker coal, having the ultimate composition: C, 78.65; H, 5.17; O, 7.22; N, 1.17; S, 1.28; Ash, 6.27; gives for its evaporative efficiency 10.5. Correcting for the average ash leaves 10 pounds. The maximum value in the test is 9.37. The average is 8.36. The number of tests on this coal is noticeably less than on the others. The average composition of the upper Freeport coal is: C, 72.65; H, 5.06; O, 8.95; N, 1.34; S, 2.89; Ash, 9.10. This corresponds to a standard of evaporation of 9.9 pounds, or, correcting for average unburned coal on the six tests made in stationary boilers, 9.4 pounds. The average evaporation is 7.53 in the stationary boilers. The locomotive tests are much below the others, averaging 6.61 pounds.

The Darlington coal, with the average composition of C, 75.19;

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H, 5.14; O, 9.05; N, 1.46; S, 1.98; Ash, 7.18; computed in the same way, gives 10.2 pounds evaporated, which, corrected for the average unburned coal, becomes 9.4 nearly. The average evaporation in stationary boilers is 7.43; in locomotive boilers, 6.55 pounds.

The Pittsburg coal has for average composition: C, 75.24; H, 5.18; O, 8.24; N, 1.51; S, 1.79; Ash, 8.00. This gives for evaporation, under assumed standard conditions, 10.2, or, correcting for average unburned coal, 9.8 pounds. The average evaporation in stationary boilers is 8.01, and in locomotives 7.89. In the locomotive tests quoted no figures were furnished me for the amount of refuse. Losses through grates and stack in the locomotives must be a large factor in the case of the more friable coals. If we unite together these computed standard evaporations of the different coals with the actual as shown in the averages of the boiler tests, we have the following table:

Coal.	Calculated evaporation.	Average actual.	Difference.
Pocahontas	10.9	9.28	1.68
Hocking	8.6	7.11	1.49
Thacker	10.0	8.36	1.64
Upper Freeport	9.4	7.53	1.87
Darlington	9.4	7.43	1.97
Pittsburg	9.8	8.01	1.79

The average difference between the calculated values and the actual evaporations is 1.73 pounds, showing that the average duty of the coals is about 1¾ pounds less than would be given under the standard conditions.

The relative values of the coals, as rated by the results of the boiler tests by the calculated values, and by the average calorimeter results, is shown in the following table; the Hocking coal is assumed as having a value of 100, and the others compared with it by dividing each result by the corresponding result for Hocking coal:

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Relative values of coal. (Hocking coal = 100.)

Coal.	By calorimeter.	Boiler test.	Calculated evaporation.
Hocking	100	100	100
Pocahontas	122	127	131
Thacker	116	117	116
Freeport	109	106	109
Darlington	112	105	109
Pittsburg	113	113	114

This table shows that a coal like Pocahontas, high in carbon and low in hydrogen, gives higher evaporation duty in proportion to its calorimeter value than those coals higher in hydrogen and oxygen, as was, of course, to be expected. The foregoing results are not sufficiently numerous to serve as more than indications, but as far as they go they show that the valuation of coal by the calorimeter and ultimate analysis gives results of importance which would serve as a useful guide in selecting fuels for steam raising. Furthermore, they show that calculations based on the averages for the seam, when such analyses are obtained by the analysis of carefully prepared samples, can be depended upon in rating the relative values of coals to the consumer.

I have not attempted here to apply these calculations to the individual results. Close correspondence in the special cases is not to be expected for reasons previously shown, but the conclusions drawn from the average results are offered as testifying to the reliability of well-known methods of heat calculations and as an argument for the more general introduction of ultimate analysis on the valuation of coals. It would appear especially desirable that public surveys of coal fields should adopt this method of analysis. The results further suggest that coal users should realize more fully that coals can be valued by analysis, and that it is important that their boilers and grates be held responsible for failure to approximate the chemical valuation.

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SHRINK AND FORCE FITS.

By Professor Jno. J. Wilmore.

[Reprinted from "American Machinist," Feb. 16, 1899.]

Last spring two of my senior class students in Mechanical Engineering, Messrs. Jno. Haralson and J. L. Wood, selected the above as a subject for thesis work. The extremely meager list of references for reading that I was able to give them led me to think that perhaps this subject had not received much attention, and an abstract of the results obtained might be of some general interest.

The experiments consisted in shrinking and forcing steel spindles into cast-iron disks, and afterward pulling some of them out, and twisting the others in the holes. A number of sound gray iron disks, about 6 inches in diameter by 1 inch thick, with a boss on one side about 2 inches in diameter by $\frac{1}{4}$ inch projection, were secured. It was specified that these disks should all be molded by one man and poured from the same ladle of iron, in order that they should be as nearly uniform in texture as possible.

A $\frac{7}{8}$-inch hole was drilled in the center of each of these disks and they were then chucked in a lathe and bored out to $\frac{63}{64}$ inch and faced. They were then reamed, first with an ordinary 1-inch fluted reamer about two thousandths of an inch under size, and finished with an adjustable reamer to one inch with an error believed not to exceed 0.00025 of an inch.

The spindles were made from a good quality of machinery steel $1\frac{1}{4}$ inches in diameter. The end for a distance of $1\frac{1}{4}$ inches was turned down to a diameter of $1\frac{1}{32}$ inches, and a shallow groove $\frac{1}{8}$ inch wide was cut next to the shoulder to allow the emery wheel in the grinding operation to clear at the end of its travel. They were then put on universal grinding machine and

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carefully brought to diameters varying by five ten-thousandths of an inch, as follows:

Number of spindles.	Finished diameter.
4	1.001 inches.
5	1.0015 "
4	1.002 "
5	1.0025 "
1	1.003 "

The end for $\frac{1}{8}$ of an inch was slightly tapered to enable the spindle to readily enter the hole; the actual surface in contact being thus reduced to 1 inch in length.

About half these spindles were then forced into the holes in the disks by means of a testing machine, care being taken to insure a straight and true entrance, the maximum pressure required in each case being noted. The remainder of the spindles had the disks shrunk on; the latter being heated only enough to admit the spindle. Some of each sort were then tested by pulling the spindle out of the hole, and the others by twisting the disk on the spindle.

The arrangement of the parts for the tension tests, may be described as follows: A disk similar to those previously described, except it had a larger and longer boss, was threaded with a $1\frac{1}{2}$-inch standard thread, to which was fitted a spindle. This, as well as all of the test disks, had four bolt holes drilled through the flange. The test pieces were then bolted one by one to this threaded disk, put in the testing machine, the spindle pulled out and the maximum pull noted.

In testing the force necessary to turn the disk on the spindle, the latter was placed on a lathe between centers. A cast-iron arm was bolted to the disk and supported in a horizontal position by a knife edge having a bearing ten inches from the center of the disk. The support for the knife edge was a piece of scantling resting on a platform scales. A heavy pipe wrench on the spindle with a "foot-ball man" at the handle furnished the necessary turning force. In the tables, the figures show the forces reduced to the circumference of the spindle in order to make them comparable with the tension specimens.

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The following tables show the numerical results. It should be remembered that all the holes were 1 inch in diameter and 1¼ inches long, the variation in diameter being made in the spindle.

It will be noted that the shrink fits are quite uniformly about three times as strong as the force fits of corresponding size, both in tension and torsion. The force fits were made without lubrication other than the small amount of machine oil adhering to the spindle on account of having been wiped with oily waste after grinding to prevent rusting. The spindles and holes were found to be smooth and in good condition after the tests. The maximum force was required to start the spindle. After movement had once occurred between the two surfaces, a much smaller force was required to start it a second time. No. 19 test piece was tried in torsion up to the limit of the scales without movement.

The figures from the table, with the exception of No. 8, were plotted on co-ordinate paper, and show some interesting charac-

Number of specimen.	Diameter of spindle.	Kind of joint.	Force necessary to start joint.	Force per square inch.	Kind of test.
	Inches.		*Pounds.*	*Pounds.*	
1	1.001	Force.	1,000	318	Tension.
2	1.001	Shrink.	5,320	1,695	Tension.
3	1.001	Shrink.	5,820	1,853	Tension.
4	1.001	Shrink.	2,200	700	Torsion.
5	1.0015	Force.	2,150	685	Tension.
6	1.0015	Force.	2,200	700	Torsion.
7	1.0015	Force.	2,800	892	Torsion.
8	1.0015	Shrink.	7,200	2,290	Torsion.
9	1.0015	Shrink.	9,800	3,118	Torsion.
10	1.002	Force.	2,570	818	Tension.
11	1.002	Shrink.	7,500	2,385	Tension.
12	1.002	Shrink.	8,100	2,580	Tension.
13	1.002	Force.	4,200	1,335	Torsion.
14	1.0025	Force.	4,000	1,272	Tension.
15	1.0025	Shrink.	9,340	2,974	Tension.
16	1.0025	Shrink.	9,710	3,090	Tension.
17	1.0025	Force.	4,600	1,465	Torsion.
18	1.0025	Shrink.	13,800	4,395	Torsion.
19	1.003	Shrink.	17,000	5,410	Torsion.

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teristics. (No. 8 was omitted because it was known to be too low, the beam of the testing machine being at rest at the top of its travel at the time the joint failed.) These points naturally resolve themselves under four heads: First, force fits under tension; second, force fits under torsion; third, shrink fits under tension; fourth, shrink fits under torsion. By reference to the curves, it was observed that the general direction or slope of the curve was about the same for the first three, but for the fourth the angle made by the curve with the vertical axis was about 30 per cent. greater. This would seem to indicate that the strength increases more rapidly with the diameter under these conditions. The question naturally arises as to how far these conditions would hold, and an interesting field for further investigation is opened up. The maximum tangential effort of 17,000 pounds, obtained in the tests, would, with a coefficient of friction of .2, give a normal pressure of 85,000 pounds, or 27,070 pounds per square inch, a pressure well within the crushing strength of the metals employed. With greater difference between the diameter of spindle and hole, it might be necessary to force the spindle into a heated disk.

It seems evident from these experiments that the shrink fit is the better of the two, but in practical work it is not always the best way but the "good enough way" that is sought. If, therefore, the force fits are good enough and can be made more cheaply than shrink fits, they will be used in every case.

Let us assume that the pressure per square inch of bearing surface between the disk and the spindle would remain constant for larger sizes, the allowance per inch in diameter remaining the same. Let this allowance be two thousandths of an inch per inch in diameter, a fair average value as used in practice. Take an engine shaft five inches in diameter, upon which a crank disk is to be forced. The length of the hole in the disk should at least equal the diameter, say five inches. Then the area of the surface in contact would be $3.1416 \times 5 \times 5 = 78.54$ square inches. Referring to the table, we see that specimen No. 13 is 1.002 inches in diameter, and in other respects complies with the conditions assumed above. It required 4,200 pounds to start

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the joint. Then $4,200 \div (3.14 \times 1) = 1,337.5$ pounds per square inch of surface in contact. Now $1,337.5 \times 78.54 = 105,047.25$ pounds, the force acting at the surface of the shaft required to start the joint.

Now a 5-inch shaft would not be likely to be found on an engine with a cylinder larger than 12 inches in diameter by 18 inches stroke. Then 105,047.25 multiplied by 2.5, the radius of the shaft, and divided by 9, the radius of the crank, gives 29,179.8 pounds acting on the crank pin at its point of maximum turning effort, required to move the joint. With a pressure of 100 pounds per square inch on the piston, this would require a piston of 291.8 square inches area, whereas a 12-inch piston has only 113 square inches, thus giving a factor of safety of 2.6 nearly. This would probably be too small to satisfy the engine builder for cranks, pistons and the like, but there are many other places in mechanical construction for which the factor would be ample. If, however, the crank should be shrunk on, the joint, according to our table, would be from twice to three times as strong, and the factor of safety would rise to a point that should satisfy the most exacting. A comparison of the cost of making a shrink fit with that of making a force fit with the keying necessary for safety, would determine in any particular case which one to use.

In conclusion, the author acknowledges the incompleteness of the tests, but hopes that the results obtained justify their publication. The men who carried on the work were young and inexperienced in the production of work having a high degree of accuracy, and as a consequence, many of the specimens prepared were rejected before being used in the tests.

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DIRECT UTILIZATION OF PRODUCER GAS IN EUROPE.

In connection with the notes in the last number of the JOURNAL on the subject of power from blast furnace gas, the following summary by E. P. Buffet, of an article contributed to "La Genié Civil" of Paris by M. Aug. Dutreux, will be found of much interest. The summary is reprinted from the "American Machinist," and gives a review of the results, so far as known, that have been obtained in Europe with the use of producer gas in gas engines. The data are part obtained from previous publications and part of the author's own collection. His conclusions are to the effect that all the objections commonly raised against this employment of producer gas can be, and have been, overcome.

Those objections are chiefly as follows:

1. Very feeble calorific power of the gas, and its variable composition.
2. Dust getting into the cylinders and wearing their mechanism.
3. Difficulties of ignition arising from the great quantity of inert gas.
4. Variations of the pressure of the gas.
5. Too great dimensions of the engine cylinders required, because of the feeble calorific power of the gas.
6. Difficulty of starting motors of high power.

In answering the first point, recourse is had to a theoretical study of producer gas by M. Hubert, Engineer of the Corps of Mines of Belgium, founded upon data obtained by Mr. Hiertz, the blast furnace manager of the John Cockerill works at Seraing, Belgium. Assuming the characteristic ratio of the operation of the furnace, that is the proportion of carbonic acid to carbonic oxide, to be .5 or .7, the calculations give, respectively, 1,166 and 1,046 calories per cubic meter of the gas when reduced to a

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standard of 0° centigrade and 760 millimeters of pressure. Actual tests of producer gas made with the calorimetric shell by Mr. Witz gave a maximum of 1,084, a minimum of 961, and a mean of 997 calories with twelve samples. This goes to prove that the composition of the gas is quite constant, and it agrees with the theoretical computation in showing the calorific power to be, in decimal units, about 1,000. In a study of the subject published in "Stahl und Eisen," March 15 last, Mr. Lurman, constructing engineer at Osnabrück, Germany, gave a mean figure of 879.6 calories. In either case the power does not seem so feeble as to preclude the use of the gas, when it is remembered that the gases made in the Dowson, Buirè-Lencauchez and other generators and employed in engines give only about 1,300 calories, and that the long step downward to them from 5,500 calorie illuminating gas was taken with facility.

M. Dutreux proceeds to calculate the available power resulting from the direct utilization of producer gas. Assuming, as does M. Hubert, following the experimental data of Messrs. Kennedy, Hopkinson and Beauchamp-Tower, that the efficiency of the engine in indicated work would be 21.1 to 22.8 per cent. and its mechanical efficiency 80 per cent., the effective work would be 16.88 to 18.24 per cent. The aforesaid experiments were conducted many years ago with engines of eleven to seventeen horse power, while to-day much larger ones are frequently employed, and contracts of guaranty sometimes provide for an effective work of 23 to 24 per cent. If, however, the minimum figure, 16.88, be taken, and it be assumed that 50 per cent. of the gas is utilized in the engine, M. Dutreux finds that a furnace plant of 600 tons production per day, such as that of the Société, John Cockerill at Seraing, Belgium, should give 18,000 or 14,000 horse power, according as the characteristic ratio of the gas were .5 or .7. The steam power actually derived from the Cockerill furnaces is 2,300 horse power. It might be possible to obtain 3,000 in the same way, but from there to 14,000, or more, which the calculations indicate as a possibility with gas engines, is a long stride.

The first attempts to employ producer gas on a large scale

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made in Europe have been undertaken in Great Britain, Belgium and Germany, the Scotch being, it is believed, the earliest in the field. The Belgians and Germans probably made their experiments independently of the British. The earliest patents upon the process taken out in England were by Messrs. Thwaite & Gardner. In the autumn of 1894 Mr. Thwaite proposed to Mr. James Riley, general manager of the Glasgow Iron and Steel Company, to apply it in that establishment, and a thirty effective horse-power "Acme" gas engined was installed by Mr. Thwaite in the Wishaw (Lanarkshire) furnace of that company to drive a lighting dynamo. A second installation of the Thwaite system has been made at the Frondigham Iron and Steel Works, near Doncaster. In the former case Scotch splint coal was used, and in the latter coke, and it appears that both installations have given entire satisfaction. The uniformity of operation of the engines would appear to be excellent. Mr. William H. Booth mentions having observed the engine at Wishaw for several hours, and that during that time he did not notice a single miss-fire. He declared also that the variations of the voltameter did not exceed 1.5 per cent. of their normal value. At Barrow 1,000 horse-power of the Thwaite system was to be installed. By this time a part of it, at least, should be in operation.

Several installations for the use of producer gas have been undertaken in Germany. Some of the German engineers have been bitter opposers of the plan, and this is the more remarkable in view of the degree of perfection attained in that country, both in gas-engine construction and in blast-furnace management. The question of dust in the gas has disquieted them a good deal. Mr. Lurman exploited, last winter, the results of one hundred and forty-three analyses and spoke discouragingly of the large quantities of dust present in the gases. He attempted to show that the producer gas of the Georg Marienhütte near Osnabrück, would deposit daily in the cylinders of a 100-horse-power engine twenty-nine liters of gas, occupying a volume of more than 100 liters. Mr. Greiner, who has published some results obtained at the Cockerill works, criticises this conclusion and maintains that the dust would probably not all be deposited in the cylinders.

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With the use of six scrubbers described by Mr. Greiner, the dust of the gas at Seraing, although considerable, was removed to a perfectly satisfactory extent. The cylinder of the large engine there, after running for three weeks continuously, showed only traces of dust. It is even stated by Mr. Kraft, of the gas so purified, that it fouled the igniting apparatus less than illuminating gas, being almost free from hydrocarbons. M. Dutreux concludes that while the arguments of the German engineers look well on paper, it is possible to purify the gas as much as need be without being obliged to have recourse, as Mr. Lurman implies, to cleaning apparatus of the costly sort used for illuminating gas.

One of the German installations is at the works of Hoerde, near Dortmund, and its results are being kept secret. On a visit to the establishment M. Dutreux observed the apparatus designed for cleaning the gas. From a conduit coming from the ordinary purifiers and going to the boilers branches a pipe leading to a dry purifier of 13 to 16 feet in diameter and some 30 feet in height. In shape it is a vertical cylinder ending at the bottom in a truncated cone. After this purifier come four scrubbers arranged in battery; finally, a large reservoir or gasometer, 50 feet in diameter, which serves to store the gas, as in illuminating gas works. The engines are intended for electric work only. It is said that a triphase current will be generated and used to operate the locomotive transporting the ladle of metal from the blast furnaces to the steel works, a mile and a half away, the traveling cranes and the accessories of the rolls, but not the blowers. The engines make one effective stroke of the piston with each revolution. It is stated that the contract under which they were furnished by the Berlin-Anhaltsche Maschinenfabrik provides for the installation first of a 150-horse power experimental engine and then of a 600-horse power one if the results of the first one are satisfactory. If the large engine is successful another of the same model is to be put in. The arrangement of the 150-horse power engine is somewhat complicated, and, in view of the large size of the other engines for this early period in the history of the new application of producer gas, an unsatisfactory result would be by no means conclusive against its value for that purpose.

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It is interesting to recall the first experiments that have been made at the Hoerde works, and which, without doubt, are also the first in all Germany. They are to be placed chronologically between those of Thwaite in Scotland and of Cockerill in Belgium. On October 12, 1895, the German Otto Gas Engine Company (factory of Deutz) put in operation an engine of 12-horse power, utilizing producer gas of the Hoerde furnaces. This engine had given 12.9 horse power with poor gas. The experiments lasted four months and a half, and gave entire satisfaction. The engine furnished 10.5 effective horse power at the speed of 200 revolutions. The indicated work was 11.75 horse power corresponding to a mechanical efficiency of nearly 90 per cent. The consumption of gas was 4 cubic meters per horse power per hour. The Otto Company did not receive the order for the new engines because they were unable to make quick enough delivery.

The Otto Company are making an important installation in Silesia, in the works of the Friedenshütte (Oberschelsische Eisenbahn-Bedarfs-Actien-Gesellschaft). The available power will be 1,000 horse power in four units, two of 300 and two of 200 horse power. A 16-horse power motor used there since September, 1897, has encountered some difficulty owing to the zinc dust which comes from the minerals employed.

At the famous Krupp works at Essen producer gas is being experimented with, as applied to a "Diesel" engine, but the results have not been made public.

In Belgium some extensive tests have been conducted at the John Cockerill works, and the results have been exploited with great freedom. The first engine—a "Simplex" made by Matter & Cie., Rouen—was put in operation December 20, 1895, and gave 8 horse power at the brake. The cylinder was 7.64 inches in diameter by 13.8 inches stroke, and the number of revolutions 210. With illuminating gas it gave 11 to 12 horse power. This shows that with producer gas an engine can give two-thirds the power that it would furnish with illuminating gas, although the calorific power of the latter is only 850 to 1,000 as compared with 5,000 to 5,500 for the latter.

It must be observed, however, that the proportion of illumi-

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nating gas used to air admitted is one to six, while with producer gas the volumes are equal. Further, illuminating gas is used under a pressure of only about four atmospheres, while the producer gas employed in the engine at the Cockerill works was introduced at a pressure of ten atmospheres in order to obtain a good efficiency.

The fifth objection raised at the start—that relating to the necessity of using extremely large cylinders to obtain power—seems now to have been answered.

The difficulties of ignition have been completly surmounted by the use of powerful and permanent electric sparks. During some observations made in 1897 not a single miss-fire was noticed. This seems to answer objection three.

The engines at Seraine have been found to operate well under any variations of pressure that have taken place—even, if we do not misunderstand M. Dutreux, when the pressure has fallen below atmospheric; and it must be borne in mind that the first engine experimented with was used without a reservoir. This tends to refute objection three.

The last objection which remains for us to examine concerns the difficulty of starting. With the small engine used in the experiments at Seraing there was some sluggishness in this particular, and the engine did not always start immediately. In a large engine of 150 horse power there employed the result was accomplished by means of pinions moved by a hand lever and acting upon the fly wheel. M. Dutreux saw this means employed at Seraing in May, 1898, and a single man succeeded in starting the engine at the first trial in one minute and thirty-five seconds. It is certain that one may without difficulty apply an automatic compressed-air starter of the nature shown by Fielding & Platt, of Gloucester, at the Brussels Exposition in 1897.

The 150 rated horse power gas engine now being tried at the Cockerill works has a cylinder of 31.5 inches diameter and 39.37 inches stroke, and a speed of 120 revolutions per minute. It is said actually to have given 203 horse power at the brake.

M. Dutreux did not know of any works in France having an

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installation of engines using producer gas. The Société anonyme des fers et aciers Robert, however, had arranged with Mr. Thwaite to install a 250-horse power engine at the furnaces of Outreau, near Boulogne-sur-Mer. A special system of purification adopted by Mr. Thwaite for coke furnaces was to be employed, and the available electric energy obtained was to be utilized at Boulogne and in the vicinity of the works.

In the Grand Duchy of Luxemburg producer gas engine installations have been made by at least two companies. At the Differdange furnaces a 60-horse power engine intended for lighting has been put in, and a 3½-horse power engine to start it. These engines, although made by the same company that furnished those of Hoerde, give two motive strokes of the piston for each revolution, which may be taken to imply that Hoerde's results did not show the ultimate of perfection. A definite trial of engines at Differdange had not been made at M. Dutreux's writing. Experiments were being conducted by the Société des aciéries de Dudelange with a small experimental engine, having in view the production of 500 electric horse power.

M. Dutreux concludes that the use of producer gas in gas engines is now becoming practicable, and that although the gas engine, because of its high speed, is not easily adapted to driving blowers it is well fitted for generating electric power for distribution throughout iron and steel mills to supplant the appallingly wasteful little engines now employed—the parasites of metallurgical works.

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CYLINDER RATIOS FOR COMPOUND ENGINES.

By George I. Rockwood.*

[Reprinted from "Power," February, 1899.]

The conviction that everything is now authoritatively settled about the design of the steam engine seems to have become a deeply rooted one in the minds of those who write text books on thermodynamics and heat engines; and, in a certain general sense, this conviction may be true. The steam engine of James Watt, considered as an automatic mechanism, was not different in any essential particulars from the steam engine of to-day. Even the compound engine was first proposed over a century ago. It is certain that the phenomenon of cylinder condensation was quite well understood at least three-quarters of a century ago, and the last word of theory may be found in Cotterill's treatise, "The Steam Engine Considered as a Thermodynamic Machine."

But though it may be admitted that it is next to impossible to devise anything really new in principle connected with the steam engine, this is very far from saying that actual steam engines to be had in the market to-day are all characterized by the same features, or that they may all be bought for the same price. One has but to examine the advertisement sheets of an engineering journal to be convinced that the problem of selecting an engine of the best kind, size, proportions and speed for a given duty is at present beyond rational solution. Shall the best engine be upright or horizontal? Single or double acting? Shall it have four valves with automatic drop cut-off, or two valves, or one positive valve? What shall be its speed? Shall jackets be used; and if so, on which cylinders? What about the real advantages of reheaters and superheaters? What shall

*Paper read before the Providence Association of Mechanical Engineers, December 22, 1898.

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be the boiler pressure? In most cases nowadays not one of these questions, so vital to the cost of the engine and steam plant, is necessarily answered by the conditions under which power is to be made, but its answer depends upon the opinion—or more likely, the prejudice—of the purchaser.

The truth is that while the modern steam engine is sufficiently complicated as a scientific and mechanical problem to account for the difficulty in estimating the relative significance of each element conducing to economy of steam, financial considerations—in other words, considerations of the net return on the total investment in the power plant—are even more fundamentally responsible for this uncertainty. Theory may show, for instance, a way to reduce a certain waste of heat by some elaboration of the steam plant; but, owing to the fact that "fixed charges" and the cost of repairs as well as of heat are also items in the total cost of power, this particular waste must perhaps be allowed to go on until the cost of the means for reducing it has itself been cut down. The cure may be worse than the disease.

The subject of this paper suggests one of the problems in the practical design of the steam engine still pressing for recognition and solution. Although great numbers of compound Corliss and marine engines have been built within the last twenty-five years, it is nevertheless a fact that next to nothing was known experimentally previous to eight or ten years ago in regard to the most economical ratio of cylinder volumes. The ratio was, and still is, fixed within narrow limits in all compound engines, whether built in this country or in Europe. Continental manufacturers have favored a proportion varying from the ratio 1 : 2.75 to the ratio 1 : 3.25. English and American builders have generally adopted a slightly larger ratio, namely, one varying from the ratio 1 : 3 to the ratio 1 : 4. A common rule is to make the diameter of the low-pressure cylinder two inches less than twice the diameter of the smaller cylinder. The explanation of this rule is found in the fact that an engine so proportioned avoids more than a very slight drop in pressure from that at the end of expansion in the smaller cylinder to the pressure at cut-off in the large cylinder, with reasonable ratios of expansion in each.

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When "drop" occurs, it is because (at least the great engineering authorities have agreed that it is solely because) free expansion takes place—that is, a sudden enlargement of the volume of a gas without doing work against a piston, as in suddenly opening a cock in the pipe joining two cylinders, one full and the other empty of gas. Since free expansion of a working gas undeniably lowers the working pressure of that gas, any loss which such a lowering of pressure would entail may be obviated by preventing the free expansion. Hence, it is said, in a compound steam engine it is best to avoid "drop."

For thirty years this reasoning has controlled the design of the compound engine. During this time boiler pressures have been increased from an average of eighty or ninety pounds to an average of one hundred and fifteen pounds or more, without affecting the cylinder proportions generally used by engine builders. In this they have been supported by most authorities. In fact, so far as I can learn, but one authority—Carl Busley, Professor at the German Imperial Academy, at Kiel—would make any change in the cylinder ratio with different boiler pressures. He gives specific ratios for various boiler pressures as follows:

Pounds per square inch	60	90	105	120
Ratio	1 : 3	1 : 4	1 : 4.5	1 : 5

In the article on the steam engine in the Encylopædia Britannica, by Professor Ewing, may be seen the following statement: "Whenever a receiver is used, care should be taken that there is no unresisted expansion into it; in other words, the pressure in the receiver should be equal to that in the high-pressure cylinder at the moment of release. If the receiver pressure is less than this, there will be what is termed 'drop' in the steam pressure between the high-pressure cylinder and the receiver, which will show itself in an indicator diagram by a sudden fall at the end of the high-pressure expansion. This 'drop' is, from the thermodynamic point of view, irreversible, and, therefore, wasteful."

This statement by Professor Ewing is fairly typical of the confident language used by all of the most eminent authorities on the

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steam engine when discussing the practical effect of "drop." It is a noteworthy fact that at the time when it was written, 1886, no one had ever made any experiments on actual compound steam engines to determine the effect of permitting "drop," even on an engine with a fixed ratio of cylinder volumes; still less had it ever occurred to anybody, so far as I know, to determine experimentally whether a gain or a loss would follow the adoption of larger cylinder ratios than that ratio which is small enough to prevent "drop" almost entirely. Since there were no experiments at hand to support the statement so positively made in the Encyclopædia Britannica, and therefore no truly scientific basis for it to rest on, one can but wonder at its almost universal acceptance both by theoretical and practical men. I am, of course, referring to the inference drawn from the last sentence quoted, to wit: "This 'drop' is, from the thermodynamic point of view, irreversible and therefore wasteful." The sentence itself is true enough; but the caution based on it is not logically connected with it, because it is too often the case that things, slightly objectionable *per se*, are inseparable companions of other things, which are necessary or indispensable.

I have sometimes thought that the impression left on the reader of "explanations" of the effect of "drop," of the sort generally found in text-books, is that "drop" produces a lowering of potential, as it were, without any compensating effect—such as would be produced by turning a stream of water on the receiver. Certainly the drop in pressure and temperature of the receiver steam produced by sudden and violent radiation or condensation is a totally different thing from drop resulting from intermediate expansion; but one might be excused for thinking that authorities lumped both kinds of waste in the same condemnation. In D. K. Clark's "Rules, Tables, and Memoranda," pages 854–855, occurs the following suggestive discussion of the influence of "drop:" "That the work of expanding steam is to be calculated from the expansion upon a moving piston only is obvious enough when it is considered that the steam may expand into an intermediate receiver and into intermediate passages without doing any work on a piston, whilst at the same time the pressure falls or 'drops' as

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the volume is enlarged. Under these circumstances the second cylinder receives the steam at a lower pressure and in larger volume than it has when there is no intermediate expansion and fall of pressure, and there is less work done, whilst the ratio of active expansion is necessarily reduced. If the second cylinder, however, be enlarged in capacity in proportion to the enlargement of the volume of the steam and the fall of pressure by intermediate expansion, the ratio of expansion and the work done in it would remain the same."

These quotations, considered by themselves, would commit Clark to the common belief that "drop," produced by intermediate expansion, causes a serious waste. He goes a little farther in the right direction than others have done, however, in the suggestion that the waste occasioned by "drop" may be balanced by enlarging the second cylinder; but he does not, in this immediate connection, draw attention to the fact that the loss in pressure of the receiver steam, due to the practice of taking more steam by volume from the receiver than it gets from the high-pressure cylinder, is accompanied by an increase of work in the high-pressure cylinder. That is, the back pressure in that cylinder is reduced at the same time with the reduction of the initial pressure in the low-pressure cylinder. Hence the loss of power occasioned by receiver expansion, though it exists, is really very much less than Clark implies in the quotation, and with high boiler pressures and moderate amounts of "drop" is, even from a thermodynamic point of view, quite insignificant. Again, it is not the statement of fact which the authority quoted makes that I take exception to, but his inference of the bearing of that statement on the design of the actual compound engine, and also, in this case, the fact that he here leaves unsaid that most important modifying consideration pointed out above. This is not to say, however, that Clark did not himself point this out in another place; but had he done so here he would not have left so unqualified a feeling of distrust toward free expansion. It simply illustrates the confusion of mind of authorities as well as builders with reference to this subject.

I have referred to the universality of the belief in the error in

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permitting "drop" in the receiver of a compound engine, and to the lack of any foundation for this belief in direct experiment on an actual steam engine. I have shown also that this belief was based on considerations derived from pure theory—in fact, from the science of thermodynamics. I myself hold, as a result both of speculation and of experience, that while the waste attributed to "drop" is a reality and its amount may be computed if the amount of "drop" is known, such waste is not necessarily a controlling factor in determining the ratio of the cylinder volumes. Indeed, it is incomprehensible to me how the distrust of receiver expansion grew to such proportions and became all powerful in the design of compound and triple-expansion steam engines. Perhaps it is the result of the idea widely held not many years ago that the real cause of "drop" was simply initial cylinder condensation and clearance in the second cylinder. The receiver space was said to be as harmful as so much extra clearance, and it is wonderful what efforts and oddities of design were put forth, especially in the design of pumping engines, to lessen the distance between the exhaust port of the small cylinder and the steam port of the larger cylinder, with a view to minimizing the alleged uneconomical influence of a large receiver volume. I believe this view is all wrong, and probably most engineers would agree with me; yet it is apparently still held in some high places.

In a leading article on "Intermediate Expansion" in "The Engineer" (London) no longer ago than 1891, occurs this passage: "All intermediate receivers, port spaces, clearances, etc., mean intermediate expansion." In the same breath the writer goes on to say, ". . . the size of the intermediate receiver has no practical influence on the performance of an engine!" It is pretty well demonstrated that what is ordinarily called clearance is a chief cause of preventable waste; and if the receiver is really to be classed in the same category with, and as an addition to, clearance, its great size would inevitably affect the steam consumption very adversely, which, as "The Engineer" says, it does not. In the issue of the second of December, 1898, "The Engineer," in a leading article on "Compression

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in Steam Cylinders," reverts to this same thought in these words: "Nothing has been said about compression in compound engines. There is, however, no room to think that the effect will be materially different, whatever the number of cylinders used, at all events so far as the high-pressure cylinder is concerned; both the others work with maximum clearance in the sense that the receivers become *ipso facto* part of them twice in every revolution." Yes, but only during admission, and in the usual cross-compound engine with large reheating receiver, the fluctuation of the receiver pressure, due to the discharge of steam into the low-pressure cylinder, is hardly greater than that of the boiler supply-pipe pressure, due to the discharge of steam into the high-pressure cylinder. In the one case, the piston of the first cylinder pushes out a cylinderful of steam into the receiver, and a somewhat larger volume is discharged therefrom into the second cylinder; but in the other case, the boiler does not make steam as fast as the high-pressure cylinder withdraws it during the period of admission, but only one-third to one-fifth as fast, depending on the point of cut off. Both cylinders therefore work under conditions practically identical, and neither boiler nor receiver can be properly classed as additional and objectionable clearance space.

Nothing but confusion can result from associating intermediate receivers in the same category with clearance spaces. It is especially incorrect to urge that "all intermediate receivers, port spaces, clearances, etc., mean intermediate expansion"—that is to say "drop." "The Engineer" has, however, been for many years a consistent advocate of the idea that "drop" was a very small influence against the economy of a compound engine.

Quite a little has been done of late years in the way of experiment to find out the effect of "drop" in marine engines. A paper was read in 1893 before the Institution of Naval Architects of Great Britain, giving the results of a feed-water trial of a triple-expansion engine with and without its intermediate cylinder. The result was very much in favor of the three cylinders, as might have been predicted under the conditions of operation. The loss due to an enormous "drop" was the cause of the inferiority of the

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performance of the compound engine. With a boiler pressure of 125 pounds the M.E.P. of the first cylinder was 100 pounds! That is to say, there was next to no expansion of the steam before release in that cylinder. This paper was considered by many engineers at that time to supply incontestable evidence of the wastefulness of intermediate expansion. That is, because a drop of 100 pounds caused a loss, therefore all drop, under all circumstances, should be avoided. But this is not the only source of information on the performance of compound marine engines in which considerable "drop" is allowed.

Mr. H. Crompton Ashlin, Consulting Engineer, of Liverpool, declared in a letter published in the "The Engineer," dated April 3, 1893, that it has been practically known for years, to some Liverpool engineers at any rate, that high-pressure compounds can be worked at 150 to 160 pounds pressure with as good results in consumption as the best triples worked at the same pressure. In a later issue Mr. Ashlin gives a short history of his efforts in this direction. His firm had at that time converted the engines in some eight steamers from old-style compounds into high-pressure compounds, the results being that, "whilst maintaining the original speed, the consumption of coal has been reduced to the same amount as would have been used if triple engines had been substituted."

Let us consider, now, what are the causes of "drop," and then, what are the advantages which accompany its moderate use.

The causes of "drop" are of two kinds. The first kind is the one we hear the most about, namely: "intermediate expansion." When more steam by volume leaves the receiver than is put into it, per stroke (presupposing that no steam is either made or condensed in the receiver itself), the receiver pressure is bound to be less than the pressure at release in the high-pressure cylinder. This is simply saying that the pressure of a gas or vapor at constant temperature bears a fixed relation to its volume. The other causes of "drop" are cylinder condensation and clearance in the low-pressure cylinder. Suppose a receiver compound engine had neither clearance or condensation in the low-pressure cylinder. There might still be any amount of "drop" if the cut-off

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on that cylinder were lengthened enough. On the other hand, if the cut-off were just adjusted right to prevent any "drop" in such an engine, and then that cylinder were endued with both the usual amount of clearance and of condensation, probably at least fifteen pounds of "drop" would be the immediate result. Again, this even then could all be prevented by making the cut-off earlier in the stroke. It is thus obvious that the point of cut-off may be a cause, or it may be a corrective, of "drop." But the point of cut-off is dependent on other considerations than its influence on the amount of "drop." As a matter of fact, it would be desirable to have the cut-off take place late in the stroke, were it not for the loss from excessive free expansion thereby involved, because this would reduce the range in temperature of the low-pressure cylinder walls, and hence would reduce the loss from initial condensation in this cylinder.

It is evident from the foregoing that unless the best point of cut off, estimated solely with reference to the waste by initial condensation, happens to coincide with that particular point at which "drop" would be entirely prevented, a compromise must be made between the gains on the one hand, to be made by lengthening cut off and thereby reducing condensation, and the loss, on the other hand, thereby incurred from free expansion. It does happen that with cylinder ratios in the neighborhood of 3 : 1 no such compromise need be made, because both considerations suggest the same point of cut off; but with larger cylinder ratios, such as 5, 6, or even 7 to 1, some "drop" is inevitable, and it becomes a question of just where to locate the points of cut off in both cylinders so as to secure a minimum net loss from clearance, intermediate expansion and initial cylinder condensation. If "drop" is accompanied by a reduction of initial condensation in the second cylinder in amount sufficient to overbalance the waste of power by intermediate expansion it is, at least, no detriment to the coal consumption to allow that much "drop." Moreover in stationary engine practice few engines drive perfectly uniform loads. Nearly all light, heat and factory loads are decidedly variable, and engines most suitable for driving such loads are compound condensing engines working with considerable "drop,"

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because this permits a widely variable cut off in the second cylinder without either looping at the end of expansion in the first cylinder or materially changing the receiver pressure. It is seen, therefore, that the advantages of "drop" are of both a thermal and a practical nature.

Having now dealt at some length with the subject of intermediate expansion and its relation to the subject of this paper, let us proceed to consider the general theory of the compound engine. As an abstract proposition, the highest economy to be realized in an engine of any type is the result of two conditions—using a volume of steam at the highest possible pressure, expanded the utmost number of times. In practice, both the pressure and the number of expansions are limited by practical circumstances; the pressure, by the increase in cost and maintenance of the boilers and piping as the pressure is carried up, and the total ratio of expansion by the increase in the waste due to cylinder condensation, friction and repairs. All authorities, I believe, are agreed that there is a certain minimum number of expansions allowable in any one cylinder of any type of engine. This number is between four and five. Now, as it happens that practically no "drop" will occur in the receiver of a compound engine having a cylinder ratio of about 3:1 and between four and five expansions in each cylinder, the custom has been, and still is, to limit the total number of expansions in such an engine to twelve or possibly fifteen. And a steam pressure of 115 pounds is about as high a pressure at it is necessary to have with such an engine to get the best economy. A higher pressure will enable the engine to do more work, but the number of expansions would remain the same, and hence the rate of steam consumption would hardly be affected at all thereby. So, if higher pressures are to be used with the object of improving the economy of the engine, the only way to do it, according to the received theory, is to add another cylinder in series. The average boiler pressure in use with the triple-expansion engine is 150 to 160 pounds. With such a pressure and with cylinder ratios of usual proportions—say 1 : 2.75 : 6.5—the number of expansions allowed in each cylinder is less than the four or five mentioned

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above. It is more likely to be 2.5 to 3. This is because 150 pounds is not nearly high enough to permit the larger number without developing too little pressure at release in the low-pressure cylinder.

The triple-expansion engine, or shall I say the multi-cylinder engine—how grand the name sounds!—holds a firm place in the affections of the college-bred engineer. What a complicated thing it is! How glorious to be able to say, "I comprehend it. I can design it and make it go without any 'drop.'" He longs for the time to come when, in the natural evolution of the multi-cylinder idea, he may have a chance of designing a quintuple, or even a sextuple, steam engine. Unfortunately for this vision, recent developments in the design of the steam engine for stationary work seem to put the time of its fulfilment yet a long distance off. In the year 1891 "The Railroad and Engineering Journal" published an article, written by myself, with this title, "How Many Cylinders Will It Pay to Introduce in the Multi-Cylinder Engine?" This was a very brief discussion of the theoretical and practical utility or uselessness of the intermediate cylinders of a multi-cylinder engine, and was written before any experimental data were available to reinforce the position taken, which was that these cylinders were of no theoretical or practical advantage as aids to the economical operation of the engine. At that time a triple-expansion engine was being constructed, and the opportunity thus presented of arranging the intermediate cylinder so that the engine could be run without it was embraced, and the following year numerous tests of this engine, with and without its intermediate cylinder, appeared to show that on that engine the second of the three cylinders was of no advantage. This was with reference to the economy of producing an *indicated* horse power. The friction of its piston and valve gear, not to mention the interest and fixed charges on the investment, made a considerable loss per *delivered* horse power.

Since the tests of this triple-expansion engine were made, eight other large engines, built by the Wheelock Engine Co., on lines which these tests indicated to be correct, have been tested by the

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following engineers: Two by Prof. Geo. I. Alden, A. S. M. E.; one by Francis W. Dean, A. S. M. E.; three by Geo. H. Barrus, A. S. M. E., and two by myself. In all, the same builders have built about 25,000 horse power of these compound condensing engines, and each engine was sold under agreement to use not over 12½ pounds of dry steam per I.H.P. per hour. In some cases the engines were not at first complete mechanical successes, and in one case this extended to the tightness of the valves and pistons, etc., causing a greater steam consumption than that guaranteed. In all of the other cases, however, so far as I am informed, the guarantee was surpassed. The very best performance of any mill engine which has been tested by recognized and competent experts is one of this type running at the mills of the Grosvenor Dale Company, and tested by Mr. Barrus, who published his report in "The Engineering Record," November 20, 1897. The steam consumption was 11.89 pounds total per I.H.P. per hour, and the coal consumption was 1.18 pounds! The average I.H.P. developed by the engine during the test was 660. If such a result as this had been announced over the signature of Mr. Barrus or any other expert a very few years ago, he would have simply forfeited his reputation for veracity for the time being. I believe, nevertheless, that a pumping engine of largest size, working with practically no clearance, with steam at a boiler pressure of 180 pounds, and a cylinder ratio of 8:1, would give the horse power on a consumption of less than 11 pounds of steam, and a coal consumption of one pound per I.H.P. per hour.

To appeal to the best recorded performance of any type of engine working under every-day conditions as to tightness of valves and pistons, as to clearances, and as to the operation of the jackets, etc., as a proof of the superiority of that type as compared with all other types, while being a thoroughly practical, is also a distinctly unscientific, manner of procedure. Besides introducing possible errors or deviations from the very best result of which that type is capable, due to unknown amounts of leakage, etc., another error to which all tests are open, namely, the instrumental one, resulting from the fact that the different engines tested are situated in different parts of the

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world and are tested by different experimenters whose personal equations are unknown, this error, I say, makes such a comparison of very secondary importance as a guide for the future. If some one having the opportunity would test the most economical triple-expansion engine anywhere to be found, working with a boiler pressure of 160 pounds, and a vacuum realized in the low-pressure cylinder of 13½ pounds, both with and without its intermediate cylinder, and have as his object to determine the heat required per brake horse power per hour, by this engine in each case. I think, but I do not, nor does any one else know, that the result would show the advantage to lie with the simpler form of engine. Such a comparative test would be a truly scientific one, and the knowledge thus obtained would be definite and compel our assent to its authority.

In the absence of such a perfect series of tests as I have outlined, we may, at least, be interested in, and allow our judgments to be influenced by, the tests made on the comparatively uneconomical and, because of its small size, low boiler pressure and poor vacuum, unrepresentative triple-expansion experimental engine in the laboratories of Sibley College, Cornell University. These tests are reported and very fully discussed in a paper in Vol. XIX of the Transactions of The American Society of Mechanical Engineers. It would be impossible to quote from the language of this paper and do justice to it within the limits of my time, and I will simply call your attention to it and quote from Mr. John H. Barr's discussion of it the figures which he presented as the water rate of this engine, run both as a triple and as a compound.

JACKETED ENGINE.

Triple	I.H.P., 141.4;	water rate, 15.37
Two cylinders	I.H.P., 152.0;	water rate, 15.58
Triple	I.H.P., 45.6;	water rate, 17.70
Two cylinders	I.H.P., 47.7;	water rate, 16 80

The compound does as well as the triple on heavy loads, and better on light loads. This paper, together with one by Mr. F. W. Dean, entitled "Trials of a Recent Compound Engine With a Cylinder Ratio of 7 : 1," cover about all the philosophy and data that are at present known on this subject.

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The answer to the question, What is the best cylinder ratio for a compound engine? depends upon the facts with regard to the loss by cylinder condensation and the loss by intermediate expansion. Little is known specifically about these facts so far as they appertain to these recent compound engines which work with high steam pressures and have very small high-pressure cylinders. As I have shown, all that we know is that high ratios and high pressures beat low ratios and low pressures; and, with the exception of the analysis by Dr. Thurston of the Sibley engine tests, we have no experimentally-derived knowledge of the details of the saving process. This analysis, so far as it goes, bears out the view which I originally entertained of the essential incorrectness of the received theory of the action of steam in a compound and in a triple-expansion engine. The deduction from that theory has been that the thing to aim at in the design of either type of engine was, besides eliminating "drop," to so proportion the cylinders as to have each cylinder do an equal proportion of work, and have the steam work through an equal range in temperature in each cylinder.

Almost the first thing that was said when the proposition to do away with the intermediate cylinder in triple-expansion stationary engines was made was that the great increase in the range in temperature in the first cylinder caused thereby would greatly increase the loss by cylinder condensation in that cylinder. My answer to that was that even if there were more condensation thus effected in the first cylinder, this would not matter unless there was such a great increase in condensation as to exceed in quantity that in the low-pressure cylinder. The singular fact is developed by Dr. Thurston's analysis, however, that the quality of the steam at cut-off in the first cylinder of the Cornell engine when operated without its intermediate cylinder was actually better than when the range in temperature was lessened by using that cylinder, and his explanation was that this was the direct result of the sudden drop in pressure at release in the first cylinder of the compound, which did not take place in the triple. Furthermore, the improvement in the quality of the steam caused by "drop" was about equal in both the high

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and the low-pressure cylinders, and was most noticeable with the most "drop!"

These experiments, at all events, make it perfectly plain that cylinder condensation does not depend directly and solely on the range in the temperature of the steam. The extent of the surface exposed, and the amount of "drop" allowed, have at least as much to do with it.

I will bring my remarks to a close by saying, finally, that I do not desire to see the triple-expansion engine discarded absolutely and for every purpose. I believe it is indispensable at sea for mechanical reasons; also for certain kinds of direct-acting steam pumps, working without cut-off in individual cylinders. But for stationary power-plant engines the most economical engine at present practically possible, all things considered, is, in my judgment, a cross-compound engine, working with a boiler pressure of 180 pounds, a vacuum of 13½ pounds, a receiver pressure of 8 pounds, and a cylinder ratio of 8 : 1.

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ROPE DRIVING.

[From "Quarterly Digest of Physical Tests."]

The use of ropes in dynamo driving has been far from common in the past, but is estimated by some as likely to be more common in the future. The truth is that the dynamo differs much from most pieces of machinery of equal bulk. An armature of small size puts an immense resistance against the driving force, and most armatures have very small momentum as compared with the power absorbed in the driving of them. Yet in electrical work, perhaps not in lighting, but at least in traction and other power transmissions, there are apt to be very great sudden fluctuations of the power absorbed. Where there is no fly wheel the stress thus produced is transmitted immediately to the furthest point of the machinery, and in direct-connected engines, the stresses which come upon the crank-shaft are very severe, and quite sufficient to account for the many failures which have taken place in such shafts. The stresses make no outward or visible sign other than any slowing down of speed they may bring about. In case of belts or ropes which are placed between an engine and a dynamo, and are called upon to suddenly take up or give out stresses of large amount, the fact is made prominently visible by the wave which is thrown into them, and heavy ropes apparently make a sudden leap which is really dangerous. This points to the necessity of using fly wheels on armature spindles exactly as they are used in cases of direct driving. But there is another aggravating cause of trouble. It is frequently the case that dynamos are placed considerably below the engine. This is a mistake. When so placed any wave thrown off the upper side of the driving rim has all its centrifugal and upward tendency allowed full play. When the dynamo is above and a wave is thrown off from the fly rim, the effect of gravity tends to pull the rope down against its centrifugally applied upward wave. As a result the rope traveling

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upward to the dynamo pulley is urged by gravity against the face of the driven pulley, whereas, in the case of the downward-moving rope, gravity is opposed by the inertia of the rope, and the wave may reach the driven pulley and get half around it before it gets down to its groove. Wherever possible the slack side of a rope should travel uphill. In short, it is unfair to blame ropes for the fault in design which is evidenced by the neglect to apply a fly wheel. Otherwise the important points in rope driving are the rope diameter, the ratio of rope to pulley diameter, the form of grooves, the distance apart of shaft centers, the material of the ropes, their velocity and the unit stresses in them.

Messrs. W. Kenyon & Sons, of the Chapelfield Ropery, Dukinfield, who have made a special study of the subject, and are the makers of the patent inter-stranded rope which bears their name, consider that though the diameter of the smallest pulley should be at least thirty times that of the rope for cotton, and forty-five times for hemp, it is nevertheless desirable to make the driven-pulley diameter fifty times the rope diameter, and the driving pulley one hundred and fifty times. As to this, however, much must hang upon other considerations. In the early days of rope driving, ropes were commonly two inches diameter, but thinner ropes are stronger per unit of sectional area. Large ropes, however, have greater durability, and becomes less worn in proportion to their weight than do thin ropes, and the general result of now many years' experience has been to fix upon 1⅝ inch as a happy medium. For large powers, seeing that ropes of large diameter will give a much greater power per unit of breadth of face of rim pulley, it is clear that the length of a heavily loaded shaft can be kept to a minimum by using large ropes. Large ropes also hang better and in more even curves, and we think that nothing should be used of less size than one and one-half inches where possible, and this would call for 45-inch driven pulleys in order that the minimum ratio of pulley diameter to rope diameter may be maintained.

The form of the groove is a matter that requires consideration. Continental makers often make the bottom of the groove flat. English practice is to make it round. This is not a matter of

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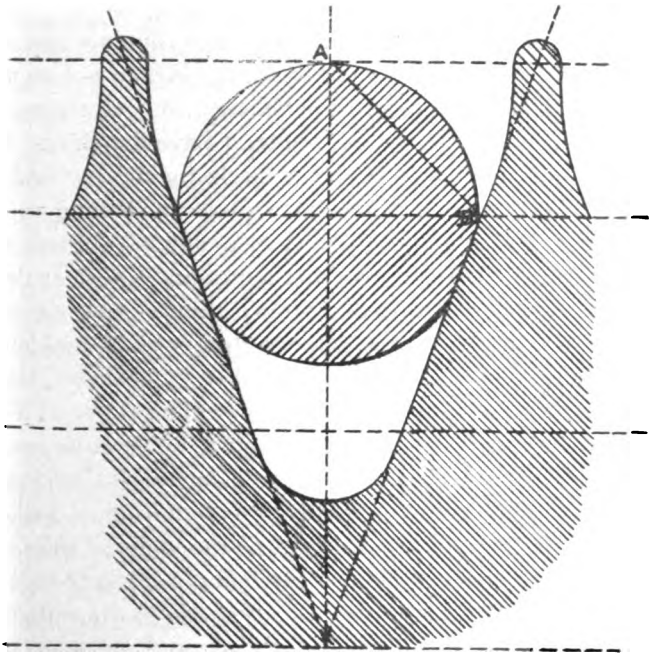
much importance. What is important in the matter of grooves is that every groove shall be of the exact same form, and they should be so made that the ropes wedge into and release themselves without much friction. Moreover, the ropes must not touch the bottom of the groove. From 40 degrees to 45 degrees is a usual angle to adopt. Messrs. Kenyon, to whom we are indebted for the annexed copyright method of designing the grooves, use an angle of about 41 ½ degrees, obtained by the construction shown in the annexed figure, as follows:



1⅝ Diameter Rope, Full Size.

Draw the circle of the rope with intersecting vertical and horizontal axes. Draw the cord, *a b*. From the center of the rope mark off on the vertical line a distance equal to *a b*, this will give the center of the root circle. Next mark off a further distance equal to *a b*, this gives the point of intersection of the sloping sides.

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Draw these sloping sides through the ends of the horizontal diameter of the rope and carry them forward till they cut the dotted line drawn horizontally across the top of the vertical diameter of the rope. The intersection is the center of the narrow flange curve. The flanges are made thin and joined by an easy curve to the inclined sides of the grooves; but this curvature should cease as shown at a distance about equal to $\frac{1}{8}$ the rope diameter above the horizontal diameter of the rope, for it is of importance that the groove sides should be flat and not curved or they will prevent the rope from bedding itself to shape. It will tend to revolve, and a rope which rotates about its own longitudinal axis wears more and never assumes the solid shining appearance which characterizes a well-wedged rope. We do not say this is the sole cause of rotation, but it is believed to have an important influence and, therefore, grooves should have flat sides. In the diagram the flattening of the rope circle by the inclined sides about represents what actually takes place in shaping a rope to its groove. Any angle sharper than about 40 degrees would cause too severe a wedging action; any more obtuse angle than 45 degrees would too seriously reduce the wedging action. It must be noted that as a rope enters a groove slack and leaves it stretched, and therefore so much smaller in diameter, the tendency is for it to occupy a lower place in the groove as it nears the point where it leaves the pully again. The rope lies, as it were, between the sides of a very long pair of inclined planes, and it is thus held from slipping by this longitudinal wedge action as well as by the frictional grip of the inclined sides. The base curve of the groove is of course simply made to touch the sloping sides; this fixes its radius. Sometimes the vertical portion of the flanges is omitted, and the sloping sides are simply joined by a curve which does not always extend so high as the top of the ropes. These do not give quite so great safety against jumping of the ropes from groove to groove. To be easy in working, ropes must not be too short, the distance apart of the shafts being conveniently three times the joint radius of the driving and driven pulleys. Any excess over this is apt to allow too much sag in cases of horizontal driving, and generally too great

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length is not desirable, especially in dynamo work, as the large amount of slack is a source whence a sudden change of stress may give rise to wave motion and shock. Too short a distance between shafts is, however, undesirable, especially where the pulleys differ considerably in diameter, as it reduces the grip arc on the small pulley to what may prove too small to secure a proper grip.

The length given is, therefore, a fair average. In a factory of several floors the ropes to the upper floors are obviously much longer than the others, but the distance in plan is not necessarily so, and the sag of the slack side is not therefore excessive. Direct vertical driving is to be avoided where possible. When a nearly direct vertical drive is unavoidable allowance has to be made for the fault by using more ropes to the extent of 15 or even 20 per cent. or more, while, where the slack side in a horizontal drive is the lower side, a percentage of 10 to 15 per cent. should be added to the number of ropes to make up for the less desirable arrangement. In calculating the power that a rope will transmit, it must be remembered that there is a wide margin of strength, but for ordinary speeds the horse power that a rope may be safely made to transmit may be set down as

$$\text{H.P.} = \frac{d^2 s}{5{,}000},$$

where d is the rope diameter in quarter inches, and s is the rope velocity in feet per minute. Thus a $1\frac{3}{4}$ rope at 5,000 feet figures out at nearly 50 H.P., and though speeds of 6,000 and even 7,000 may be employed, it must be remembered that for the stresses used in practice 5,000 feet per minute is the maximum velocity beyond which the stresses due to centrifugal tension increase at a faster rate than the increase of power. Beyond 5,000, therefore, a rope is really less efficient. The limits of practice are conveniently from 2,000 to 6,000 feet velocity, but there is no objection to slower speeds when needful. One should aim to get a speed of 3,600 to 4,800 where possible. Between these limits a rope has practically an equal efficiency. As regards material the first driving ropes employed in heavy driv-

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ing were of hemp, because it was in Dundee that rope driving was first employed. Americans use manilla very much, but manilla is a very rough fiber and works its own destruction, and nothing has proved so good as cotton. Egyptian and American cotton are those most suitable. There is practically no difference between them.

As regards the question of electrical driving it may be thought that an elastic rope which has a considerable slack will be more objectionable than a tighter rope. In this respect we understand that arrangements are being made to test the properties of Rhea fiber as a material for driving ropes. Rhea fiber, which is the strongest fiber known, and is a fine, smooth fiber of great length and capable of being spun fine like cotton, has exceeding little elasticity and would therefore make ropes that would stretch very little, and would, at the same time, be as free from internal friction as cotton.

The question of strands is one of importance. Any one who will draw three circles in contact, and four circles in contact, will see at once that there is only one arrangement for the three circles in a rope. With a four-strand rope two opposite circles may touch, and the other two may not touch, and a four-strand rope tends to become irregular in shape. There is, therefore, no reason for having more than three strands to a rope. They form a more solid rope than any other number. A four-strand rope requires a core to help it in its proper laying. A core makes a rope stiffer, and, moreover, it is very apt to take above its share of load. This may break it, and the vacant gap between its broken ends is occupied by the rope getting out of shape and the space becoming filled by one of the strands. Other numbers of strands also require a central core, and are exposed to the same liability to get out of shape as the four-stranded rope, and three strands have now become the standard.

With a material like cotton, the pliable nature of the strands allows them to so interbed themselves as to practically fill solid the center space, and, after some time of working, a rope which has become bedded assumes an almost triangular shape and gets hard and compact, and, if suitably dressed with a minimum of

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dressing, becomes polished on its bedding sides and runs almost like an iron bar in appearance. Dressing should only be very sparingly applied, and on no account in sufficient quantity to soak the rope. Dressing contains plumbago, and while this helps the rope to become polished the liquid portion of the mixture is supposed to be present simply in sufficient quantity to lay any fluffy ends. A mixture much used on machine ropes is one of plumbago and treacle or syrup. Oil must not be used. It is usual when making a cotton rope to lightly serve with plumbago and tallow the outer surface of each strand before laying up the rope, but this is all that is needed; there should be no composition between the individual threads.

It may be added, in regard to speed and the folly of running ropes, by intention, at specially high speeds, that even the speed of maximum efficiency is really not the most economical speed. It allows of the use of minimum rope pulleys, but the wear of a rope is a result of its speed, and, at 5,000 feet the wear is 25 per cent. additional to the wear at 4,000 feet, yet the working capacity of the rope, alowing for centrifugal stresses, is under 3 per cent. more at 5,000 feet velocity than at 4,000 feet. Indeed, the wear may be doubled by raising the speed from 2,500 to 5,000 feet, and less than 40 per cent. will be added to the capacity.

The Lancashire practice in rope gearing has so fixed the ratio of working stress in the rope to its weight per foot and centrifugal stress that the velocity of maximum capacity coincides with the 80 feet per second usually considered as the maximum safe velocity for a cast-iron rim. The maximum velocity has been found to produce the best results, but here again the results so obtained are merely a coincidence. They are good because of the excellent fly-wheel effects which accompany high rim speeds, and not necessarily because of the high rope speed, and, speaking generally, there have always been so many considerations in the whole question of main driving, that certain results have been very commonly attributed to wrong causes. Ropes have been run with perfect satisfaction up to speeds as high as 7,000 feet per minute, developing, per 1¾-inch rope, some 93 H.P. This implies not simply an increase in the centrifugal ten-

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sion, but also in the working tension, and is not to be recommended on the score of durability, because at that speed the tension on the rope is 427 pounds due to centrifugal tension, 438 due to working side pull, and probably 86 pounds due to the slack side tension, a total of 950 pounds, which is quite 50 per cent. more than usually allowed.

Early rope installations attempted to employ ordinary shaft bearings, and a good deal of trouble naturally followed with heated necks. The high rotative speeds coupled with the heavy side pulls of the ropes, and the absence of the vibration which was set up when toothed wheels were used, combined to cause trouble, and bearings for rope-pulley second-motion shafts have grown in length up to five diameters of the neck. To prevent bending and enable a shaft to be of minimum diameter, the supports have been placed close to the pulleys, or have been made double, with enlarged central diameter of shafts, and continuous oiling pumps are fitted to maintain a constant flow of oil over the necks, the pumps being driven by bands from the shafts themselves, a pump and an oil box and circulating pipes being fitted for each bearing. The necessity for large area of bearings arises from the steady pull of the ropes and the very continuous pressure upon the brasses tending to exclude oil. Brasses need to be suitably channeled to lead the oil in, but there should be no through oil hole drilled into the oil channels of the loaded brass, nor should the channels extend to the ends of the brasses whereby a too free escape of oil is allowed.

In the question of multiple independent ropes or of the single rope reduplicated, there are, of course, arguments to be advanced on both sides, but the weight of evidence and experiene is in favor of the multiple system. With this system the grooves of the driving and driven pulleys are exactly opposite to each other, and this is not the case in the system of reduplication where the grooves have a lateral relative displacement of half a groove. The rope entering No. 1 groove of the driving pulley leaves No. 1 groove of the driven pulley it is true, but the rope as it enters the No. 2 driven groove has left the No. 1 groove on the driver, and finally when every groove is followed out the rope has to be brought back to the starting point right across the full breadth

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of the driving drum, and there must be a carrier pulley for this purpose.

The angular direction of the ropes relative to the grooves causes lateral rubbing and tends to cause the ropes to revolve upon their own axes. This tendency is mischievous, for when a rope revolves it never beds itself to shape in the grooves, and will not have the endurance of the bedded rope. Where the single rope is employed it is wound the necessary number of turns round and round all the pulleys to be driven, every turn, of course, passing round the main drum. Thus, with the grooves in the main drum and four equal driven pulleys, each driven pulley takes four laps of the rope, which also is carried once round a sheave carried by a tension carriage. The advantage of this system lies in the ability to regulate the slack side tension to a uniform minimum in each lap of rope, and it is more suitable also for vertical drives, the tension carriage serving to take up all the surplus slack which would otherwise cause the ropes to slip. But for most ordinary straightforward work the independent ropes are preferable. It is probable that the system of reduplication, more used in America than here, was introduced to America from Germany. English arrangements of machinery are rarely made of the style which calls for direct vertical driving, and efforts are generally made to secure a sufficient horizontal distance between shafts to allow of comfortable working with not unduly tight ropes. In such cases the system of separate ropes has so many advantages over the reduplicated single rope that it is not worth while considering for such situations a system which requires the complication of a tension carriage. In dynamo driving, especially where the dynamo is provided with an adjustable base, allowing an unduly slack set of ropes to be tightened up, the independent rope system is freed of the one fault that might be urged against it.

When the strength of a rope is considered, it is obvious that if a cylinder of parallel fibers or yarns be twisted together, the external yarns will be made much shorter than the inner ones, so that in a strand thus simply twisted together, the outer yarns will be exposed at the same time to the heaviest stress and the greatest amount of wear. The tendency of this is to cause a

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rope to wear much more quickly than it would otherwise do. If we take a three-strand rope, each strand is equally situated as regards position and twist, and as regards the strands there is no weakening. Now, Messrs. Kenyon & Sons, recognizing the evil of unequal stress, brought out their interstranded rope. In this rope each of the three strands is composed of a considerable number of smaller strands coiled layer by layer upon an inner set of strand. If a piece of rope be cut off, say exactly four inches long, each of its three strands will measure a trifle over four inches, but they will be equal because they will all be equally placed in the rope. If now one of these strands be peeled, its outer layer can be removed and will freely leave the inner portion; this may in turn be peeled, and so on, one layer after another being removed, and if the little strands of each layer be measured when laid out straight, it will be found that those first peeled off will be the longest. This is correct, because they have as many turns per foot length of rope, and are wrapped round a larger circumference. In the patent interstranded rope, therefore, every small strand has a length suitable to its place in the rope and takes its proper stress, and every thread in the rope follows its proper course and does not vary from its position throughout the whole length of a rope, unlike where a rope strand is simply composed of so many thousand threads twisted together with less attention to this important point.

In tests made by Kirkaldy a rope of $1\frac{1}{4}$-inch diameter broke at 12,017 pounds.

This system of manufacture facilitates the making of ropes any length. Numerous ropes have been made 4,000 feet long without a joining, and from $1\frac{3}{8}$ to $1\frac{3}{4}$ diameter. In fact, the limit of length is that of convenience of carriage of the bulky roll.

In splicing a rope a special man ought to be employed, and at least seventy-two diameters of a rope ought to be the length of a splice. Carefully spliced, with due regard to the gradual tapering down of the strands, a splice neatly finished is very little less in strength than the body of the rope, and after a short run it is often impossible to find the spliced portion. The approximate weight of a good cotton rope is as follows:

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Diameter of rope.	Weight per foot.	C.
$1\frac{1}{4}$ inches,	0.5 pounds,	64
$1\frac{3}{8}$ "	0.6 "	53
$1\frac{1}{2}$ "	0.72 "	44
$1\frac{5}{8}$ "	0.844 "	38
$1\frac{3}{4}$ "	0.98 "	33
2 "	1.3 "	25

A good figure to remember being that a $1\frac{3}{4}$ rope weighs 1 pound per foot, and other sizes in the ratio of their diameters squared. The coefficient, C, is useful in determining the stress due to centrifugal force for any velocity, the square of the velocity in feet per second divided by C giving the stress in the rope due to speed, and serving to calculate the stress for any speed from which the margin remaining for useful work can be deduced. Thus for a $1\frac{3}{4}$ rope the centrifugal tension at 80 feet per second is $\frac{6400}{33}$, or 193 pounds.

The maximum usual tension is 600 pounds in such a rope. Deducting a tenth of this for the slack side tension leaves 540, from which, if 193 be taken, we have left 347 pounds working load. For a total of 600 pounds stress the maximum speed of the rope would be found at about 77 feet per second, but when wear and tear is taken to account, the paying maximum speed will be found even less than this, the true value being dependent upon the cost of ropes and the cost—initial—of the pulleys, etc. It must be noted also that at a high velocity the initial tension requires to be greater, because of the reduced grip due to centrifugal tendency, and this again tends to lower the speed of maximum efficiency.

It is a mistake to suppose that rope gearing absorbs so very much more power than belts or toothed gears. A roped engine may show a greater friction diagram, but the cause is one rather of fly-wheel weight, and the heavy rims used for ropes have been found very effective in promoting steady running, and necessarily add to the friction of an engine. For steady, continuous work the year through and freedom from breakdown and anxiety, the use of large engines and rope gearing can hardly be rivalled by any other system. But armatures ought to have their fly wheels in the same way as they are supplied in direct driving, namely, upon the spindle of the amature.

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SPECIAL NICKEL, CHROMIUM AND SILICON STEELS.*

By A. Abraham.

In the first part of his paper the author speaks in a general way of the use of nickel and chromium in the manufacture of steel, but more especially in regard to its application in the manufacture of armor plates. As far back as 1878 the steel works of Holtzer in France made thin plates (four milimeters), containing chromium, for the French navy, while it was only ten years later that the Creusot manufactured for the first time two lots of armor plates made with nickel steel for one of the French ironclads. These plates are supposed to have contained 0.30 per cent. of carbon, 0.5 per cent. manganese and 2.5 per cent. nickel. The results of two plates of that composition, tested on the proving ground, were inferior and showed the steel to be very brittle.

The Creusot works, undaunted by such results, continued in that line and had the satisfaction to establish the supremacy of nickel plates in the now famous international tests that took place at Annapolis in October, 1890. In this test, as is well known, the nickel steel plate furnished by Creusot was found to be superior to an ordinary steel plate manufactured by the same concern and to a compound plate from Cammell & Co., of Sheffield, England.

After these remarkable tests all the large armor-plate makers took up the manufacture of these special nickel plates, and after some further testing it was well established in 1892 that nickel plates, containing chromium in some cases, were superior to all other plates, more especially in regard to resistence to perforation.

In a tabulated form the author submits the chemical analyses

* Abstract from the Annales des Mines by J. B. Nau, reprinted from the "The Iron Age" of Febuary 2, 1897.

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and the results of the mechanical tests obtained with a certain number of samples taken from armor plates, of which some contain nickel, others chromium, and still others both nickel and chromium. Without going into any further details of this long table, we may state that the results of the mechanical tests, even with only small differences in the chemical composition, vary greatly in the different steels. These variations are mostly due to the treatment to which the steel is submitted. A very small variation in the temperature of the hardening as well as the annealing operations may in a large measure change the mechanical properties of the metal. The table shows in a very marked degree the high limit of elasticity obtained with some of the steels as compared to their ultimate resistance after tempering and annealing. With an ultimate resistance of about 70 kilograms per square millimeter (99,540 pounds per square inch), ordinary armor plate steel has an elastic limit of only 40 kilograms (56,880 pounds), while steel with 1.5 per cent. of chromium and no nickel has an elastic limit of 50 kilograms (71,100 pounds), and steel with 2 per cent. of nickel and 0.75 per cent. of chromium one of 56 kilograms (79,632 pounds).

The analyses of the steels here quoted, taken from the table, are as follows:

	Carbon.	Silicon.	Manganese.	Chromium.	Nickel.
Ordinary armor-plate steel	0.45	0.20	0.50	.....	.....
Chromium steel	0.46	0.16	0.43	1.52	.....
Nickel and chromium steel	0.31	0.16	0.35	0.75	2.05

Furthermore, the "stricture" ratio of the difference between the original and the reduced area after breaking on one side and the original area on the other side in some cases is higher than 60, even when the ultimate resistance is above 80 kilograms per square millimeter (113,760 pounds). (The stricture is equal to $\frac{a - a^1}{a}$, where a equals original cross section of test bar and a^1 the cross section in the region of the rupture.)

The drop tests for both nickel and chromium steels show little

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brittleness but great malleability, even in the cases of steels with an ultimate resistance of 90 kilograms per square millimeter.

Few tests have been made concerning the influence that hardening and annealing have on the qualities of nickel and chromium steel. The author, however, quotes the results of the mechanical tests made with steel obtained from two 10-inch armor plates. The metal contained about 0.40 per cent. of carbon, 0.80 per cent. of chromium and 2.5 per cent. of nickel. The plate had first been forged under a 50-ton hammer, then rolled lengthwise and crosswise. The first plate was afterward annealed at a cherry-red heat, hardened at a temperature of 900 degrees in water at 65 degrees centigrade. This last temperature was maintained as much as possible. After this the plate was again annealed at a temperature of 550 degrees, but the metal at this state being still too hard a second annealing at a temperature of 575 degrees was resorted to. The straightening was done under a hydraulic press at a temperature of 550 degrees. The second plate was hardened in water at 75 degrees without any previous annealing. The hardening was followed by two further annealings, during the last of which the plate was straightened.

A table showing the results of the mechanical tests to which the metal of the two plates was submitted before hardening, between hardening and the first annealing and after the second annealing is published by the author. This table shows that hardening increases the tensile strength of the metal, decreases its elongation, but increases its stricture. Now, the stricture constitutes a very important element in regard to the kind of the local deformations that take place during the test of thin plates. It is due to this high stricture after hardening as well as to a mere tendency to crack that the nickel and chromium steel is so superior to the ordinary carbon steel in the manufacture of armor plates.

Another plate of nickel and chromium steel rolled but not hammered, annealed at a bright cherry red (about 950 degrees) before hardening, then twice hardened again at 950 degrees in water and finally annealed after hardening at a nascent cherry red (about 800 degrees), was submitted to mechanical tests in its natural state and again after it had been submitted to the above

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operations. The table published on this test shows that hardening and annealing increase considerably more the elastic limit than the ultimate resistance, and that in spite of a reduction of about 4.5 per cent. in the elongation the stricture is considerably increased.

Where it was desired to obtain a very hard plate, as high as 1.10 per cent. of chromium was added, together with 2.15 per cent. of nickel. Chromium when alone hardens steel but little, but in presence of nickel it makes it possible to obtain a plate which, when tempered at a cherry-red heat and annealed at 550 degrees, had an ultimate resistance of 90 kilograms (127,980 pounds) and an elastic limit of about 80 kilograms (113,760 pounds).

Dead soft steel containing about 1 per cent. of nickel, after having been hardened at a cherry-red heat and annealed at a dark-red temperature, becomes entirely fibrous or has a fine, dull grain. Steel with about 1.5 per cent. of nickel has an ultimate resistance of more than 40 kilograms (56,830 pounds); its stricture is noticeably decreased. Yet the metal, well treated, is not brittle.

THE USE OF NICKEL IN THE MANUFACTURE OF GUN STEEL.

The following analysis of steel was adopted in 1894 by the steel works of Imphy for their gun metal: Carbon, 0.30 to 0.50; silicon, 0.20 to 0.25; sulphur, 0.01; phosphorus, 0.015; manganese, 0.38 to 0.42; nickel, 2 to 2.25, and chromium, —. This metal can be forged without difficulty at a somewhat bright cherry-red heat. After annealing at a dark-red heat test pieces, cut crosswise, gave the following result: Elastic limit, 35 to 38 kilograms (49,770 to 54,036 pounds); ultimate resistance, 55 to 60 kilograms (78,210 to 85,320 pounds), and elongation, 19 to 20 per cent.

Similar test pieces, hardened at a cherry-red heat and annealed in a wood fire with long flame, gave as result an elastic limit of 50 to 52 kilograms (71,100 to 73,944 pounds), an ultimate resistance of 65 to 70 kilograms (92,430 to 99,540 pounds), and an elongation of 16 to 17 per cent. With metal containing

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2.5 per cent. of nickel and 0.5 per cent. of chromium about the same results are obtained.

Steel with more than 2.5 per cent of nickel has a tendency to crystalize. Fine crystals in the shape of long, narrow needles form in the heart of the ingot. These crystals will not disappear either by forging, annealing or hardening. Rolling places the crystals lengthwise. Test pieces cut crosswise have crystalline fractures without elongation or stricture. Drop tests are impossible. The author speaks further on of similar results obtained with nickel steel in the United States. He states that in some works steel containing about 3 per cent. of nickel can with the right treatment be made to have a resistance varying between 60 and 95 kilograms per square millimeter (85,320 to 135,090 pounds). With an ultimate resistance of from 75 to 85 kilograms (106,650 to 120,870 pounds), either a great elongation or a high limit of elasticity with high stricture and only little elongation can be obtained.

HIGH NICKEL STEELS.

The author, speaking of this class of steel, quotes the very first tests made with high nickel steels and publishes some tables on the tests made in 1888 by James Riley of Glasgow. These tests were made on a great number of steels, of which the lowest contained 1 per cent. and the highest 49.4 per cent. of nickel. Without entering into any further details we may state here some of the principal conclusions drawn by Mr. Riley from his tests. High nickel steel is easily made in the open hearth; the metal is fluid and homogeneous. Forging and rolling require no particular precautions, except in the case of 25 per cent. nickel steel, which must be heated less than ordinary steel. Nickel increases considerably the elastic limit and the ultimate resistance without much decreasing the elongation. Steel which otherwise would not be very hard, when containing about 10 per cent. of nickel becomes very hard. The presence of nickel between amounts of 10 and 25 per cent. in the steel counteracts the hardening action of carbon and increases the elongation. In one sample of such steel containing 0.82 per cent. of carbon and 25

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per cent. of nickel an ultimate resistance of 67 kilograms (95,274 pounds) was obtained with an elongation of nearly 50 per cent. When the nickel reaches 50 per cent. in the steel the metal loses its qualities.

Steel with a high percentage of nickel acquires a beautiful polish. It resists corrosion much better than ordinary steel. It has been noticed that it requires ten times more time to corrode to the same degree a 5 per cent. nickle steel than it would require for ordinary soft steel with 0.18 per cent. carbon, and it requires 15 times more time when, instead of comparing with soft steel, this comparison is made with a steel containing 0.40 per cent. of carbon and 1.60 per cent. of chromium. If, instead of 5 per cent. nickel steel, a 25 per cent. nickel steel is considered, the same ratios will be 87 and 116. These results have been obtained by plunging the test piece in water containing muriatic acid.

Up to 5 per cent. nickel the steel can be easily machined; with more nickel this becomes more difficult. Steel with 1 per cent. nickel welds well; with more nickel this quality decreases.

At the Cockerill Works at Seraing, Belgium, a series of tests were undertaken in 1894 for the purpose of obtaining a steel with a very high limit of elasticity, great ductility and malleability. The best results were obtained with a ferro-nickel, or compound of nearly pure iron and nickel. The engineer in charge of the tests established a comparison between this metal and an open-hearth carbon steel which as far as possible should give the same hardness. The analyses of the two metals follow:

	Ferro-nickel.	Carbon steel.
Carbon	0.06	0.55
Silicon	0.01	0.20
Sulphur	0.02	0.03
Phosphorus	0.016	0.047
Maganese	0.35	0.70
Nickel	7.50	...

Some of the results of the mechanical tests to which the two steels were subjected are as follows:

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	Limit of elasticity in kg. per sq. mm.		Resistance per sq. mm. in kg.		Elongation.		Contraction.	
	Ferro-nickel.	Carbon steel.	Ferro-nickel.	Steel.	Ferro-nickel.	Steel.	Ferro-nickel.	Steel.
In their natural state.....	40.5	51.6	54	86	24.3	12.1	60.4	24.4
Hardened in water at 900 degrees.....	107	53.2	125	73.8	10.2	2.2	50.5	0.9
Hardened in water at 900 degrees; annealed at 500 degrees.....	82.3	80.2	82.7	102.9	12.5	7.7	61.2	27.3
Hardened in oil.....	97.3	71.6	99.6	93.4	9.3	1.8	42.3	4.7
Hardened in oil, annealed at 500 degrees..	81	78.8	84	106	12.2	9.8	52.5	27.3

The table shows in what respect ferro-nickel is superior to carbon steel. But it must also be stated that when hardened the above ferro-nickel retains a silky fracture, similar to the fracture of the non-hardened material, while the fracture of the hardened carbon steel is dry and granular. Blow tests break at once the hardened carbon-steel test bar, but simply bend without cracking the hardened ferro-nickel test bar. Further tests made on tests bars of ferro-nickel of the above composition and on homogeneous iron of the same composition but without nickel, have shown that when submitted to transverse action or bending the elastic limit was found to be 27.9 kilograms per square millimeter (38,874 pounds) in the case of homogeneous iron, and 50.9 kilograms (72,380 pounds) in the case of ferro-nickel. Leaving the price out of consideration, ferro-nickel is superior to homogeneous iron in every respect.

Some French steel works have made a series of methodical researches on different nickel steels. The most complete researches seem to have been made by the Saint Jacques Steel Works at Montluçon. The results obtained by the mechanical tests of these steels permit a classification of the metal into three different groups:

1. Steel containing 2 to 5 per cent. of nickel. Their resist-

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ance increases with the percentage of nickel, especially when the carbon content is low. When carbon reaches 0.50 per cent. or more, the presence of nickel has little influence. Steel of this class forges and rolls well. When hardened, the ratio of elastic limit to ultimate resistance becomes very great.

2. Steel containing from 10 to 20 per cent. of nickel. The resistance increases again with the amount of nickel. An addition of 0.10 per cent. of carbon increases the ultimate resistance from 30 to 65 kilograms (42,660 to 92,430 pounds). Such steel containing 20 per cent. nickel has a resistance of 110 kilograms (156,420 pounds). If at the same time the carbon increases up to a certain limit, a resistance of more than 200 kilograms (284,400 pounds) can be obtained. The upper carbon content at which the resistance of a 10 per cent. nickel steel begins to decrease again is 0.50 per cent.

Steels of this second class do not harden much, and do not harden at all when their carbon content is higher than 0.10 per cent. Twenty per cent. nickel steel never hardens. All are very brittle. They forge and roll well, but when containing more than 0.10 per cent. of carbon they cannot be machined.

3. Steel containing from 20 to 25 per cent. of nickel. Their elastic limit as well as ultimate resistance is low. They have great elongation and are nearly free from brittleness. When forged at a low temperature without annealing their elastic limit increases notably and has reached 55 kilograms per square millimeter (78,210 pounds), with an ultimate resistance of 80 kilograms (113,760 pounds), and an elongation of 25 per cent.

With carbon content of less than 1 per cent. the steel can easily be forged and rolled. Steel with 1 per cent. of carbon can be forged between 500 and and 1,000 degress with light blows. Machining is difficult but not impossible. From these tests it results that only the steels of the first and third classes can be used for practical purposes, the steels of the second class being too brittle and too difficult to machine.

NICKEL-CHROMIUM STEELS.

In his second chapter the author analyzes the qualities of steels containing both nickel and chromium. This class of steel

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has been thoroughly tested by the steel works of Imphy in France. In 1894 these works had received an order for two kinds of nickel steel or ferro-nickel, one to be very soft, not susceptible to being hardened, but with a very high elongation just before breaking; the other to be very hard, susceptible to be worked with a tool and have the highest possible elastic limit. Without entering into any of the details submitted by the the author, we reproduce here the analyses of some of the typical steels that were especially manufactured and thoroughly tested by the steel works before satisfactory results were obtained.

	N. 1.	N. C. 1.	N. 2.	N. C. 2.	N. W. 1.	N. C. 3.	N. C. 4.
Carbon	0.05	0.412	0.610	0.455	0.566	0.535	0.760
Silicon	0.035	0.221	0.326	0.385	0.232	0.527	0.469
Sulphur	0.030	.....	0.035	0.034	0.029	.....	.....
Phosphorus	0.048	.....	0.010	0.029	0.120	0.011	0.013
Manganese	0.085	0.288	0.245	0.410	0.500	0.324	0.360
Nickel	25.88	5.65	24.72	24.150	24.320	24.86	24.960
Chromium	.....	1.03	.....	0.413	.....	1.420	2.88
Tungsten	.....	.....	.....	.....	2.05	.....	.....

Steel N. 1 had in the ingot all the characteristics of a 25 per cent. nickel steel. Numerous crystals in the shape of fine needles started normally from the surface toward the inside of the ingot. These needles cut each other on the two diagonals of the square cross section. The center of the ingot is composed of small crystals placed without order. In regard to some results of the mechanical tests, we will briefly state that steel N. 1 was very difficult to work; it could be cut with a tool made of soft steel. Its ultimate resistance was 90 kilograms (127,980 pounds), its elongation 4 per cent. It gave no satisfaction. Steel N. C. 1, which was intended to have a high elastic limit, could not be practically utilized on account of its extreme hardness. The annealed metal had an ultimate resistance of 70 kilograms (99,540 pounds), the hardened metal of 135 kilograms (191,970 pounds).

Metal N. 2 was intended to take the place of N. 1 with a higher percentage of carbon and was expected to give better results in regard to hardness. While there was some slight improvement in that respect it was far from sufficient. Since this sample showed that carbon alone would not produce the desired results, it was

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deemed advisable to try additions of other metals, and sample N. C. 2 was obtained with an addition of chromium. This metal forged well, especially when forging was begun at a low temperature. It rolled well. Its ultimate resistance was 77 kilograms (109,494 pounds), with 52 per cent. of elongation. One test bar of it was annealed and elongated 30 millimeters. This special test bar was annealed ten times in succession, and the aggregate elongations are claimed to have been 342 millimeters, or 242 per cent. A drop test could be repeated 15 times on the same bar, the bar being turned each time; it broke only after the fifteenth drop. This metal is remarkably tenacious, and even after having been deeply cut it was broken only after many difficulties.

With all these qualities the steel was difficult to work and failed to have the desired hardness. Tungsten was then tried in sample N. W. 1. This metal forged well. A rolled bar in its natural state had an ultimate resistance of 86.7 kilograms (123,287 pounds), with 41 per cent. elongation. Annealed, its ultimate resistance was 78.5 kilograms (111,627 pounds), with 44.5 per cent. elongation. The metal does not harden, can be worked a little better than N. C. 2, but it failed again in the right hardness. Tungsten having failed, chromium was again tried, but this time in larger amounts. See sample N. C. 3. This metal forges well. It is more easily worked than N. C. 2, and its hardness has considerably improved. While not yet entirely satisfactory it showed conclusively that by the use of chromium in the right proportions the best results would be obtained. The metal N. C. 4, with about twice as much chromium as in the previous sample, was then made. This metal forges well and has sufficient hardness. It works well cold.

The hardening operation has on the metal the same effect as annealing. In its natural state its ultimate resistance is 104 kilograms (147,888 pounds), with 19 per cent. of elongation. Annealed at a cherry red it withstands 99.5 kilograms (141,489 pounds), with 29 per cent. elongation. The elastic limit was observed to be 60 kilograms (85,320 pounds). On another sample the elastic limit was found to be 73 kilograms (103,806 pounds), with an ultimate resistance of 95 kilograms (135,090

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pounds), and an elongation of 29.8 per cent. Some other compositions of metals were tried. Some contained more chromium, others contained, in variable quantities, tungsten, nickel and chromium. In still other samples the amount of manganese was variously increased with the suppression of chromium. The results in all the cases, however, were inferior to what had been obtained with the metal N. C. 4.

After having satisfied themselves by numerous tests that a composition similar to the one of the metal N. C. 4 was the best for their purpose, the Imphy Steel Works began to manufacture the metal in large quantities in the open-hearth furnace. We reproduce here the details of the very first charge of this kind in the open-hearth furnace as typical of all other heats. The bulk of the nickel, of 1,100 kilograms was introduced in the furnace with the charge. Further 300 kilograms were added after the fusion of the charge. At the end of the operation 350 kilograms of ferrochromium were introduced, and finally, a few moments later, the ferromanganese was added for deoxidizing and recarburating purposes. The whole heat lasted 6¼ hours and was made very successfully. Fifty-seven hundred kilograms of finished metal were obtained from a charge of 5,910 kilograms. This constitutes a loss of only 4.4 per cent. The metal contained 20.06 per cent. of nickel and 3.16 per cent. of chromium.

A test piece cut lengthwise from a rolled bar had a resistance of 97 kilograms (137,934 pounds), with 34 per cent. of elongation. Two test pieces cut crosswise from a rolled bar were also tested. The first one, in its natural state, had an ultimate resistance of 80 kilograms (113,760 pounds), with 28.4 per cent. elongation; elastic limit, 44.2 kilograms. The second test bar, three times hardened, had an ultimate resistance of 77 kilograms (109,494 pounds), an elongation of 42.6 kilograms (60,577 pounds) and an elastic limit of 36.6 kilograms. Numerous tests were made with the metal of this heat. All these tests are fully reported on by the author. We will only state here that the metal forges well, but is hard enough not to be much influenced by the hammer when its temperature falls to cherry red. Small superficial cracks appear during the forging process at each

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heating, the chiseling of which is very difficult, on account of the chisels wearing out quickly. When heated too much or unequally the metal becomes brittle.

From one ingot, weighing 1,600 kilograms, a gun tube was made. Its forging was easy, but in the lathe it exposed numerous little veins all placed longitudinally on one side of the tube. One test bar of this metal taken from the end of the tube after nine successive reforgings had a resistance of only 69 kilograms (98,118 pounds), with 21.5 per cent. elongation. The fracture looked like rotten wood. This phenomenon was probably due to crystallization that remained in the metal, which had probably been forged at too low a temperature in order to avoid cracks. The metal from the same test bar being three times in succession plunged in water at a cherry-red heat, the crystallization disappeared, the ultimate resistance rose to 73 kilograms (103,806 pounds), with 50 per cent. of elongation and a stricture of 54. The fracture of this bar was silky.

Bending tests of a peculiar kind were resorted to. The machine to make these tests is a lathe so arranged that a square test bar fastened with one end normally to the end plateau of the lathe will revolve around its center line at the end fastened to the plateau of the lathe. The other end of the bar is not fastened, but is bent upward and kept there by means of a transverse iron bar, laid higher than the axis of the lathe and normally to this axis. When the lathe revolves, the end of the test bar fastened to the lathe will revolve with it, while the free end of the bar, lifted up, will also revolve around its own eccentric axis, but not around the axis of the lathe. The result will be a continuous bending of the test piece successively on each of its faces in the section where it is fastened to the machine, and finally the breaking of the bar in this section.

A bar of the above metal in its natural state was submitted to 42,000 revolutions of the lathe without breaking. Ordinary steel of about the same resistance and annealed at a cherry-red heat broke after 13,273 revolutions.

The same metal was also extensively tested in castings, but the results not being satisfactory this practice was abandoned.

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We will state only that from the many casting tests made the conclusion is arrived at that the peculiar crystallization of which we have already spoken cannot be avoided and is considered as one of the great causes of failure. Annealing was tried to improve the castings, but while some improvement was noticed partial crystallization still happened. The operation of hardening constituted a very great improvement, without, however, doing away entirely with crystallization. Hardening, however, is a dangerous operation to be applied to castings.

During the numerous tests to which this steel, N. C. 4, was further submitted, and which are fully reported on by the author, practical points in regard to forging and machining have been noticed. The temperature at which the metal can be worked must not be higher than very bright cherry red nor lower than cherry red. We quote here that a heavy ingot, weighing 3,588 kilograms, which was transformed into a rudder for one of the vessels belonging to the French navy, was put in the heating furnace at 5 o'clock in the morning while the heating furnace was at a dark-red temperature. For two hours the ingot was left to heat up slowly until it reached the temperatare of the furnace. The heat of the furnace was then slowly pushed until, at 2 o'clock in the afternoon, a very bright cherry red was obtained. The piece was then forged step by step. Some parts of the rudder required as many as twenty-three successive heats before their final shape was obtained. During these operations at different times superficial cracks opened either on one or several faces or in the corners. Good care was taken to remove these cracks before proceeding any further. At one time, to remove cracks that had formed in one of the corners, two complete heats were required. Outside of these cracks no serious defects were noticed. The operation of forging such metal, on account of the narrow limits within which this operation can be done, is necessarily very slow.

The tools that were used in the machinery are slow working. They are mostly chromium or tungsten tools. One tool, containing 0.60 per cent. of chromium and 2 per cent. of tungsten, gave satisfactory results when hardened at a dark-red heat.

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Another tool, with 2.5 per cent. of chromium and 9 per cent. of tungsten, required no hardening. This tool also contained 2.16 per cent. of manganese, which made it possible to forge it easily. The one tool that gave the greatest satisfaction and which can be forged, hardened and tempered easily, contained 6.5 per cent. of tungsten and 0.8 per cent. of chromium.

Tables showing the itemized cost price of one rudder shaft made of nickel chromium steel and a cost price of a rudder shaft made of soft steel were submitted. They show that the first rudder cost 3.51 times more than the last one. In these cost prices labor enters for about one-quarter and steel and fuel for three-quarters in the case of the soft-steel rudder shaft. In the case of the nickel-chromium steel rudder shaft labor enters for one-eighth and steel and fuel for seven-eighths. In these prices the shafts are considered of the same size. But a nickel-chromium steel shaft, on account of its greater strength, may be 23 per cent. less in diameter than a soft-steel shaft, or 41 per cent. in volume. Under these conditions the price of the nickel-chromium steel shaft is only twice as high as the one of soft steel.

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EARLY STEAMBOATS.

By Chief Engineer Geo. W. Baird, U. S. Navy.

The very interesting chapter by Mr. Haswell in the last issue of the Journal, has led me to submit the following notes on the earliest steamboats that came to my notice.

When a small boy (1855), I visited Baltimore with my father, and while there he pointed out a steamboat that he said was about thirty years old. My recollection is that her name was *Kentucky*. She was built by Watchman and Bratt, at Baltimore, where my father had been foreman. She had a square engine, with a single cylinder, about 30 inches diameter of bore, and about 7 feet stroke of piston. The cylinder was cast in two pieces, because they had no means of making so large a cylinder in one piece. Each half was bored out separately; the flanges were chipped and filed by hand, then bolted together; and then the cylinder was bored out again. It seemed they had no lathe that could face the flanges, and the hand job was pointed to in great triumph; it was regarded as the very acme of the art of chipping, filing and fitting. The vessel had originally a wooden shaft; later, a cast-iron hollow shaft, and, finally, a wrought-iron solid shaft.

Another very successful boat, built at Baltimore about 1830 by the original "Charlie" Reeder, was the *Columbia*. She had a pair of overhead beam engines, about 40-inch cylinders, and about 10 feet stroke of pistons, and was "very fast;" but she shook so badly that they removed one engine and one boiler. Her boilers were copper, and were used up to 1855. She had a new and larger engine put in during '58. She made weekly trips between Washington and Baltimore up to 1861, when she was withdrawn in consequence of the war.

My recollection of these vessels is that their connecting rods, links, air-pump rods, &c., were all polished, and the stub

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ends handsomely finished. They had single poppet valves, and it required a powerful man to handle their starting bars. The *Columbia's* cut-off was a butterfly valve in the steam pipe. For this the Sickles cut-off was substituted early in the fifties; its details were not well worked out; it tripped only when the valve was lifting, so could not cut off beyond half stroke. The saving of fuel due to the improved cut-off was considerable, but the owners refused to pay what they had agreed (a percentage of the saving), which resulted in that famous lawsuit in which Mr. Dickerson won the unique distinction of becoming an engineer by the use of words instead of acts.

U. S. SHIP *UNION.*—The engines of the *Union* were designed by Mr. William Ellis, whom I knew well, who was master mechanic at the Washington Navy Yard, and who was one of the best engineers of his day. The wheels were invented and patented by Lieutenant W. W. Hunter, who spent much of his private fortune on their development. The hull was built and shaped to accommodate the engines. It had two beams, on deck, 33 feet 6 inches, and at the wheels, several feet below the water line, the beam was reduced by a reverse curve to 26 feet; the bottom was flat and the turn of the bilge was sharp.

As a ship she was possessed of many bad qualities; slow under steam and slow under sail; could not be made to "lay to" nor keep the wind with head sails set and hauled flat aft; the center of gravity of the load line and transverse area were so far aft as to make her unmanageable in a sea way.

The engines were two in number, were non-condensing, and independent of each other. One engine turned each wheel. The wheels were similar to paddle wheels, but were mounted on vertical axes, working in drums inside the hull, with the width of a paddle extending beyond the side. Mr. Hunter saw the advantage of getting the propeller under water, that it might be protected from the enemies' shot. Following are some of the principal dimensions.

Diameter of steam cylinders, inches	28.
Stroke of pistons, feet	4.
Nominal horse power	159.
External diameter of wheels, feet	14.

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Vertical length of paddles, feet	4.
Breadth of paddles, inches	10.
Number of paddles in each wheel	20.
Number of boilers	3.
Type of boilers	Cylindrical, tubular.
Total area of grate surface, square feet	159.
Total area of heating surface, square feet	2,800.
Length of each boiler, feet	18.
Diameter of boilers, feet and inches	6–5

COST.

Of hull	$87,864.00
Of engines	53,187.00
Of boilers	13,754.00
Of extras and alterations	17,670.00
Total original cost	172,477.00

PERFORMANCE UNDER STEAM IN DECEMBER, 1844.

Boiler pressure, pounds per square inch	80.
Mean number of revolutions per minute	26.
Cut-off, from commencement of stroke, inches	24
Mean number of pounds of coal consumed per hour	2,200.
Indicated horse power developed by the engines	300.
Mean speed in nautical miles per hour	5.
Pounds of (Cumberland) coal per I.H.P. per hour	7.333
Percentage of loss in propelling instrument	54.

Lieutenant Hunter commanded the *Union* when she was commissioned, but she never left the coast. Larger boilers were subsequently put in the vessel, and some alterations were made to the wheels. A pressure of from 70 to 100 pounds was carried in the new boilers, but they were soon ruined by scale. In 1846 she was again "repaired" and new engines, 40 inches in diameter and 4 feet stroke of piston, put in. These were condensing engines; "new arches" were put in the boilers and the number of paddles in the wheels was reduced by one-half. On trial she made seven knots.

In fairness to Mr. Ellis, it is proper to say that he designed the original non-condensing engines under orders, after urging the advantages of a condensing engine. The original engine was designed and built under the administration of the Board of Commissioners, but the new one was built after the bureau system was inaugurated. The machinery of the *Union* was condemned and taken out at Philadelphia in 1848.

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MALLEABLE CAST IRON.

By Erastus C. Wheeler.

[From "The Iron Age," February 16, 1899.]

The manufacture of malleable cast iron at the present day is accompanied with a vast quantity of what might rightly be called contradictory knowledge. This has been occasioned in no small degree by the close attention given each local condition, to the exclusion of that confidence in the art which has so beneficially encouraged its former rival, gray iron. There has been, and is still prevalent in many quarters, a decidedly sensitive feeling that malleable iron founding is somewhat of a metallurgical secret. And this fact may in a measure account for the lack of literature published bearing upon the subject. This industry, comparatively speaking, is still in its infancy. From its humble and praiseworthy efforts in the early thirties to make itself a known factor in the arts, it has developed so rapidly in later years that its product is now a recognized and highly essential article of commerce. It has crept slowly, and with many a hard-fought battle to its credit, into the very strongholds of gray iron, and, once there, has never been overthrown.

As in the modern evolution, it is the strong against the weak, and this competition will continue until it has a dominating position in the metal-casting world. When that point has been reached it will be the turning of its great success, for then, and not until then, will the moment be ripe for the advent of its successor. Already the commercial world has heard a faint whisper as to what the aspirant will be, and has recognized with some little financial encouragement several attempts at its production. But the day for a metal which shall be malleable without the long annealing operation, and which will present a surface comparing favorably with the material of to-day, is many years hence, and present plants have nothing to fear in that direction. The

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year just closed has marked the highest tonnage in its history. Its adaptability to an almost unlimited variety of work makes it at once a most necessary article of construction. It has almost entirely superseded gray iron in freight-car building, and its entrance into the great field of agricultural supplies will be, as its former trials, a success. In the carriage and saddlery-hardware branches the malleable casting presents an indisputable article of superiority over the hand-forged article of twenty years ago. The uniformity and smoothness of its surface together with the homogeneous nature of the metal insure its great demand in the commercial world.

In no other branch of the metal world has the tonnage increased so markedly compared with a former year as the malleable casting. Recent and reliable figures place the tonnage for 1898 as 50 per cent., increase over 1897. The enlargement of present plants, the building of new works and the contemplated erections for the early season of 1899 are due indications of the great success of this most staple article. A better feeling has developed during the past few years (and this is best proven by the large attendance of malleable makers in conventions) toward advancement of the art, without those jealous restrictions of past years. There is no secret about it, and one maker may be more successful through executive ability and care in details, rather than in marked superiority of finished article.

The entrance of the chemist has been productive of larger benefits than in the gray-iron industry. The careful selection of raw material for mixture, and thoughtful analyses presented, have all tended toward an advancement which has been unprecedented in the casting art. The promptness of blast-furnace management to go on malleable burdens and meet the requirements of specifications, which are now closely confined, but which will broaden, has been one of the most encouraging features of all.

The greatest barrier was the prejudice of people (used to gray-iron weight) to the lighter and stronger article. But these battles have been won, and the malleable casting is no longer a matter of doubt. It is the purpose of this article to deal with the effects, for good and bad, of the impurities found in pig iron.

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They are taken in the order in which, according to latest practice, their importance is placed, and beginning thus we have silicon.

THE INFUENCE OF SILICON.

Of all the metalloids contained in pig iron, this is probably the one upon which the greatest dependence is placed. It is conceded that silicon promotes the separation of graphitic carbon, and in the malleable casting these two metalloids are destined to assume important parts. It might be well to trace the formation of silicon back to the blast furnace, and endeavor to comprehend a few of the chemical phenomena incident to its production. In all the material charged into stack, fuel, limestone and ores, silica is present in varying quantities. When the charge has passed the fusion zone the reduction is complete and the chemical reaction from silica to silicon has taken place. The amount of silicon and carbon contained in pig iron will depend in a great measure upon the good working of the furnace. If the latter is operating very hot a high-silicon product will result, but if the furnace, through atmospheric conditions or otherwise, is cold the low-silicon white iron is made. Why the furnace conditions govern the amount of silicon present is a question rather of blast-furnace practice than of malleable founding, but there is one patent fact, which should be clear in every foundryman's mind—namely, that the term silicon means "heat."

In calculating mixtures for the casting of light work the percentage of silicon is usually kept high, and the amounts of other alloys (with the possible exception of phosphorus) do not differ materially from mixtures made for heavy work. A metal is desired which will retain its heat for a considerable period, and the resource for it is higher silicon. Gray iron will contain its heat much longer than air-furnace metal, pour smaller work, and yet its appearance does dot denote this propensity. It will be argued the carbon exerts great influence in this matter, and there is, no doubt, weighty truth in it, but the main and lasting factor is silicon. Gray iron is hot of its contained latent energies, while malleable metal is hot mainly through the induced heat of the furnace, together with its lesser silicon. Burn the silicon and carbon com-

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pletely out, and a metal resembling steel will result, which cannot be poured with success in green sand molds, but which requires a hard surface for metal to run over. It is poured under pressure, because its life has been completely eliminated, through the loss of its alloys. How often has malleable metal appeared hot and yet has misrun the patterns? Silicon from its origin in the ores as silica, through the blast furnace, into pig metal, and the reduction of the latter in reverberatory furnace, as malleable, is the synonym for heat units. Without its dominating presence in mixture iron will not remain hot and liquid to the successful casting of light work. It is a great necessity. Silicon in conjunction with manganese affects the shrinkage of metal materially.

The term shrinkage must not be misconstrued as a reduction in values or weights, but the contraction incident to cooling. If the annealing process were carried through without its attendant loss of silicon and carbon, castings would be of the same dimensions as when cast, the expansion having equaled the contraction. The higher the percentage of silicon the longer the metal will remain hot after pouring, and with a reduced shrinkage, the lower silicon, the more rapid cooling will take place, with greater contraction. As regards the heat of malleable metal, there are many times when iron is not only too hot of itself, but with the induced heat of blast will, after pouring, present the elements of segregation to contend with. This latter difficulty is caused by the internal pressure generated by the center being the last part of casting to cool, drawing the already cold exterior inward. When a chill is applied to these affected spots there is another feature presented—namely, internal shrinkage—and is caused through the surface being chilled, and as exterior cools the strains generated and the resistance met with cause the iron to strain and pull apart, leaving the familiar shrinkage spots in centers. It has been general practice until a few years ago to place heavy risers upon all large castings, in order to "feed" the same properly during the period of cooling, but this has been discontinued, owing to metal segregating under heads, leaving a hole visible upon the surface. These

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defects have been overcome through the agency of another metalloid, manganese, which will be described later on.

Malleable iron has not as yet reached that point where it could be compared with gray iron, regarding the uniformity and homogeneity of fracture. Perhaps this may be considered a metallurgical impossibility, but yet it is hoped for. There is a very reliable test for the amounts of silicon required in mixture, and careful manufacturers place great confidence in same. A test bar exactly 12 inches long and ½ inch thick is cast from every heat, and a micrometer reading is made off same. If the shrinkage is found to be greater than that allowed in patterns the silicon has been too low; if the contraction has been less the percentage of silicon was high, and it then resolves itself into a question for manipulation to adjust this, the idea all through being that a high-silicon liquid iron will cool slower, with less contraction, than a low-silicon, duller iron, with its greater shrinkage.

The presence of a large percentage of silicon will assert itself when after annealing the fracture will show a wide, white edge and is brittle. The non-removal of silicon in appreciable amounts may be due to the fact that it is not acted upon by the carbon dioxide during the process of decarbonization. Silicon grades the pig iron, being, as before stated, a promoter of graphitic carbon. Foundrymen are looking forward with interest toward a more universal method of grading. A great many malleable concerns who do not employ chemists, but who accept furnace analyses, and who in a degree regulate their mixtures with regard to the appearance of the pig, are often misled by the appearance of graphitic carbon. In one grade, pigs showing the large open crystals and some the close grain will be found, yet in silicon these may vary appreciably. The open grain will be the lower silicon and higher carbon, the closer grain the higher silicon with less carbon.

If the grading were always accepted the open fracture would have been called the higher silicon. These two fractures are occasioned by the slightly different casting manipulation at blast furnace. The amount of silicon in mixture for light and heavy

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work will, of course, be governed by purely local practice, and no general rule can be laid down for same, as no two furnaces work alike. What would be a general average places the percentage for light work from 0.80 to 1.30, and heavy work from 0.65 to 0.95. In air-furnace practice there often occurs a condition when iron is hot enough to pour, and yet great difficulty is experienced in combining carbon. The very general opinion would be that the iron used is too soft, too high in silicon, and a change is made for lower percentages of same. It may be argued that the higher silicon prevents the combination of carbon in the bath, and yet, if that heat were brought up slower and skimmed earlier, the carbon would have combined readily, and at the proper moment would have been ready to pour, showing distinctly a heat condition rather than an improper mixture. All these annoying problems can be met and remedied by judicious experiment and metallurgical knowledge of a chemist, who should be thoroughly competent to diagnose each phenomenon and advance reliable theories. A great many of the most successful malleable foundries are conducting their business without the aid of a laboratory, yet it is a source of great satisfaction to those who employ chemists to really know why existing defects are possible, and that suggestions may be made for guarding against their repetition.

In preparing a mixture for the air furnace the nature and general dimensions of patterns to be cast are the first considerations. In the large foundries, where the castings are heavy, the pig iron selected for the furnace is chosen with reference to its low silicon and total carbon. The grading of iron will serve as a guide in this particular, a mixture averaging about No. 3½ producing a very satisfactory working in the furnace. An excess of silicon must be avoided, in all cases, because it will produce an inferior brittle article of high tensile strength and no appreciable elongation. There should be a clear understanding in this matter, that while the presence of silicon is a necessity in the melting furnace it is a hindrance to good product after the annealing process. There should be a total loss of at least 40 per cent. silicon from the original mixture to the finished material. Some will be lost

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in melting and the balance during annealing. In the following tables this fact will be found clearly demonstrated, the test being taken from regular heats. Where there has been a decided loss in silicon the percentage of elongation has been good, and with a uniform tensile strain:

No.	Tensile.	Elongation.	Silicon.		
			Mixture.	*Soft.*	*Per cent. loss.*
1	46,800	7.32	0.88	0.52	41
2	45,600	8.22	0.80	0.40	50
3	45,000	4.72	0.76	0.45	41
4	43,610	5.33	0.79	0.52	34
5	46,600	5.83	0.73	0.48	34
6	45,600	4.50	0.80	0.40	50

In the following heats the percentage of silicon excluded has been low, and we still find high tensile strength with a small percentage of elongation, and consequently a much stiffer iron:

No.	Tensile.	Elongation.	Silicon.		
			Mixture.	*Soft.*	*Per cent. less.*
1	45,600	2.25	1.09	0.90	18
2	42,500	2.13	0.77	0.66	14
3	34,900	2.33	0.79	0.68	14
4	37,500	1.83	0.76	0.73	4
5	35,000	1.83	0.79	0.68	14
6	37,400	3.12	0.77	0.59	23

In all these tests the percentages of the other alloys have remained practically constant. Sulphur has averaged 0.043, phosphorus 0.124, and manganese 0.58. If the result of thoughtful research and careful study is to be accepted as conclusive, it would prove the theory that a too-high silicon will not be conducive to good malleable iron. There could be several good reasons advanced in explanation of the fact why the silicon is eliminated in the one instance and remains practically constant in the other. A faulty annealing is one, and an improper combination of silicon and manganese another. Silicon and carbon, working in certain ratios with each other, will not be effectually eliminated by the weak decarbonization of a slow and cold-working furnace. The whole theory of the malleable process is to decarbonize the metal through the aid of an oxidizing reagent, and this is brought about by the use of prepared packing in some

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instances, or any substance which has an affinity for carbon under heat. The lower the percentage of carbon and silicon in any metal known to the metallurgist the softer and more malleable it will be; the higher these elements the more brittle it will become. This fact is very prominent in the manufacture of steels.

Malleable cast iron is, therefore, the direct result of decarbonizing cast iron by means of a sesquioxide which will impart a portion of its oxygen to the carbon in the metal at an annealing heat, producing CO, burning the carbon.

THE INFLUENCE OF SULPHUR.

Of all the metalloids found in the composition of pig iron used for malleable purposes, sulphur probably exerts the most negative influences. It is only dependent upon heat conditions in the blast furnace for its existence in pig iron, and when the furnace is working excessively hot there is hardly a trace found. In the case of coke irons, the fuel used has a direct bearing upon its presence. It has a very serious effect upon the regular malleable casting and must, of all the impurities, be most avoided. There is, however, a grade of semi-steel upon the market at present, called McHaffie, which up to a certain point is nothing more than malleable, but which requires a high percentage of sulphur in its production.

This excess sulphur produces a very high combining carbon point, making it possible to pour castings with a diameter of 24 inches perfectly clear. After the annealing, which requires about eight days, the metal presents an entirely different appearance from ordinary malleable, the fracture showing (when the conditions have been favorable throughout process) a crystalline surface, closely resembling an open-hearth steel casting. The sulphur is added to mixture in the form of a sulphide of iron, and about two pounds per ton produces the metal described above. This metal is used with great success in castings requiring a wearing surface with no great elongation or reduction of area in physical tests. The whole idea of the process is to combine the carbon to a point not possible in the malleable casting. In the manufacture of coke iron in the blast furnace, we have in the

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fuel used a high percentage of sulphur, and while the furnace is working hot there is no difficulty experienced in eliminating it, through the high volatilization, and also through the slag. But with the changing conditions of heat, the furnace working cold, we find the iron absorbing sulphur in large quantities. Thus in a No. 1 iron sulphur is at a minimum, and in a No. 6 at a maximum. In charcoal irons this feature does not present itself, as the fuel used is very low in sulphur, and a No. 1 or No. 6 varies but slightly in this particular.

We fail to observe any beneficial results arising from the presence of sulphur, and the lower the percentage of it in malleable the more satisfactory will be the product. If, like in the McHaffie process, sulphur could be added in the furnace and carbon combined higher and then volatilized in annealing ovens, we could derive some benefit from it. But with the existing methods of producing and handling malleable cast iron, there is no good excuse for its presence. Sulphur enters readily into combination with the iron, but never, like the other metalloids, loses its individuality (so to speak). It has an all-pervading, permeating tendency to dominate the metal to the serious detriment of its good quality. It destroys early in the process the clinging qualities of the molecules, and high-sulphur hard iron will break very readily. No better example of this can be found than when breaking off gates, particularly if they are heavy, while with low sulphur we meet with some degree of resistance in this particular. In calculating percentages for mixtures it has always been found good practice to use irons varying completely in chemical analysis, for the benefit of obtaining good averages. In this connection it might prove interesting to note the fact that a great quantity of high-sulphur coke iron, made at furnaces during a period of cold working, is thoroughly applicable to good malleable, if used with judgment. We have here an iron low in silicon, high in combined carbon, and with what appears an excess of sulphur. If sulphur averages about 0.75, and is used with irons of about 0.02, we would have another iron to choose from, instead of resorting to the higher priced

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grades. As many furnaces recharge this material, a selling price considerably under market quotations could be obtained.

The writer has used many hundred tons of this iron, and when sulphur was kept within 0.045 in the initial charge experienced no trouble from it. With 0.045 in sulphur the limit of safety has been reached. Above that percentage there is danger. That fact will assert itself without fail in the annealed casting. The tendency of high sulphur is to produce "shortness." When making Bessemer steel, after an ingot has been reheated and annealed in the soaking pit, and is introduced into the rolls, and there falls apart like cake, there is but one verdict, "red short," viz: high sulphur, there being absolutely no life in it, and the presence of this alloy has destroyed its tenacity. So with malleable. While we may be able to secure a reasonably high tensile strain, yet the elongation is nothing, and the iron has a short, sharp break. The presence of an excess of sulphur in annealed castings may be detected by the appearance of fracture, coupled with surface indications. On the surface will be found many slight flaws. Taking a draw bar, for example, on its barrel will be found small, and what are apparently shrinkage cracks, extending inward about $\frac{3}{8}$ to $\frac{1}{2}$ inch. The fracture, too, will show a crystalline break, often mistaken for cleavage or underannealing. Both of these mentioned defects will be overcome by the reduction of the sulphur in the mixtures. In offering malleable castings to the commercial users an article possessing ductility, and not high tensile strength, is what specifications should call for. In the case of railroad castings, the softer the product the better it will withstand the sudden sharp strains incident to car service.

In this connection it might be well to approach the physical requirements of the malleable cast iron coupler. It should be "soft," not over 42,000 pounds tensile strength, and with an elongation of at least 8 per cent. in 6 inches. When the tensile strength runs higher we find, after a severe coupling has been attempted, the head of coupler upon the track, instead of attached to the barrel. Malleable iron is a refined cast iron, and in this one instance must not be compared with open-hearth steel, for the claims thus made are not reliable. The relation of

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sulphur to the breaking strain is very prominent indeed, and must not be overlooked in any instance. In a lot of 100 malleable couplers returned to a concern during the past year, 80 were found to have been cast in one week, and in every case the head was broken off short at the barrel. The percentage of sulphur in these castings averaged 0.095, and the iron used was a high coke, carrying as per analysis furnished, 0.065 sulphur. If the melter had been better acquainted with blast-furnace working he would have at once questioned that analysis as improbable.

The chemical action of sulphur in the anneal is not as clear as we would desire, but from the fact of its combining the carbon higher the anneal should be shortened perceptibly. It is not at all beyond the range of possibilities that in the coming decade we will have a basic lining brick used in the air furnaces which will eliminate both sulphur and phosphorus as effectually as is now done in the basic Bessemer and Siemens-Martin furnaces. Necessity will advance this process at the proper moment, and it will throw open a wonderful field for iron now debarred to the producers of malleable. At present the sellers of pig metal for use in malleable shops find themselves restricted to rather narrow margins on specifications. Years ago the same conditions prevailed in relation to iron for use in the open-hearth furnaces, owing to the rigidity of government and other specifications, and with this necessity came the dolomite lining for vessels and furnaces. It is not that the elimination of sulphur in the ores is an impossibility; in fact, this is a highly accomplished modern operation. To free the fuel used in the blast furnace from it and also control the furnace regarding heat conditions is quite another matter. The fuel used in air furnaces must be selected with care—bad fuel is poor economy. Iron will be longer in melting, and while in the liquid state will quite readily absorb sulphur. High-grade coal is the cheapest and, while phenomenal runs have been made with an inferior quality coal, the iron produced has not been correspondingly phenomenal.

In purchasing pig iron, if there exists a doubt in the buyer's mind as to correct analyses, specify Bessemer limits all through.

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You will then have an iron which may not be exactly what your melter wishes, but you will be safe. There should also be more leeway given in specifications for pig iron, but the manufacturers are not willing to become any broader in their views on account of what may be local ideas and practices. For years a concern have been making malleable in one way, and have been using the same grades, and are therefore unwilling to hazard anything on new analyses. But this cannot continue. The times are changing in malleables as they have in steel in the past, and the day will come when we will have to accept what is offered. Then the up-to-date concerns will be the only ones alive and doing business.

The question has often been agitated as to whether objectionable impurities in molten metal could be absorbed or eliminated in the air furnace by the use of a flux. The writer has made many trial heats in this direction, and with fair success. In charging heats a quantity of limestone was placed on the bottom, with a small percentage of fluor spar. After the charge was melted the first skimming was delayed to allow the limestone sufficient time to attack the silicon. This was accomplished, reducing same about 0.40 in furnace. The fluor spar acting upon the sulphur and phosphorus also gave the most encouraging results. There is, however, a great tendency for the limestone to cut the bottom and side walls, but with an extra coating of ground crucible shells this was avoided.

No better illustration may be had of the affinity of iron for absorbing sulphur than from the fact that a modern blast-furnace burden, which carries 0.035 sulphur, produces a metal having as high as 0.250 sulphur. This occurs, of course, when furnace is cold. The same may be said of an air furnace. When an inferior grade of coal is used the heat is slow coming up. There must be no liberty taken with sulphur above 0.045, if successful castings are to be produced.

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ELECTRICALLY OPERATED 150-TON JIB CRANE AT NEWPORT NEWS SHIPYARD.*

By Walter A. Post.

[Reprinted from "Marine Engineering," January, 1899.]

Together with the demands of the day for greater capacity, greater power and greater speed, as essential characteristics of the modern ship, there comes the dependent feature of greater weight, and, to the shipbuilder, the problem attendant upon this feature, namely, that of providing for the economical handling of these weights.

The plant of the Newport News Shipbuilding and Dry Dock Co., although well provided from its origin with appliances for handling material, was found in its later developments to be in need of apparatus more powerful and convenient than the 100-ton sheer legs which, to that time, had been used for handling the heavier weights installed on board ships during the fitting-out period.

The growing need of such apparatus had been for some time forcing itself upon the attention of the company, but it was only in the srping of 1896 that it was finally determined to undertake its provision, and steps were taken to ascertain from the experience and opinions of experts, both in this country and abroad, what general type of machine would most satisfactorily fill the particular requirements of the Newport News plant.

The fundamental requirements, briefly stated, were: Capacity to lift and place on board the heaviest single weight liable to be incurred in the probable development of modern ships; a field of operation, as large as practicable, in which these weights could be handled, and absolute precision within this field; a location

* Read in the Sixth General Meeting of the Society of Naval Architects and Marine Engineers.

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accessible by the ordinary means of transportation from all parts of the yard; and, finally, that greatest factor defined in all projects by the broadest use of the word economy.

Careful consideration of these requirements lead to the adoption of a 150-ton revolving derrick, electrically operated and controlled, mounted on a steel tower supported in turn by pile foundations. The structure was located on one side of a pier 700 feet long, forming one side of a slip, in which a number of ships may be moored at one time and readily brought within the field of the derrick's operation. Two standard gage tracks over entire length of pier afford means of transportation from any part of the yard, and also direct connection to the main lines of the Chesapeake & Ohio R. R. System. The floor of the pier, 185 feet in width, furnishes ample room for the temporary reception of heavy pieces, castings, armor, etc., and permits, in addition, the assembling of much work within direct reach of the derrick, thus allowing assembled parts to be placed on board as a single member, relieving the tendency to overcrowd floor space in the shops and effecting a saving in cost over work as assembled on board ship.

The final design of the derrick was taken up about March 1, 1897, and in July, 1898, sixteen months later weights were being placed by it on board the battleships in course of construction at the yard.

Aside from the steel work in the tower, it was designed, constructed and erected by the Newport News Shipbuilding and Dry Dock Company, under the direction of Somers N. Smith, at that time general superintendent of the works. The design of the derrick itself, including steel tower, jib, hoists and machinery in general, was prepared by the steam engineering department under C. F. Bailey; the direct working out of plans and details being assigned to R. L. Lovell, of the same department. The successful completion and high efficiency of the whole machine attested both the care and skill of the designers and the workmanship of the yard force. The steel tower was furnished and erected by the Berlin Iron Bridge Company, of East Berlin, Conn.; while the foundations were designed and constructed under the direction of the author.

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A brief statement as to size, capacity, range of operation, etc., may be of interest before proceeding to the description of particular details.

The derrick jib is capable of having its outer end raised or lowered, thus giving to the hoisting blocks, which depend vertically from this end, a movement not only of rotation about the center of the derrick, but also of translation in or out from this center. With the outer end of the jib in its lowest position the hoisting blocks will, on rotation of the derrick, describe the circumference of a circle 207 feet diameter; with the jib in its highest position these blocks, on rotation, describe the circumference of another concentric circle 88 feet in diameter, thus permitting the derrick to operate on weights lying anywhere within the circle ring whose maximum and minimum diameters are 207 feet and 88 feet respectively. The maximum load of 150 tons can be handled only within a ring whose maximum and minimum diameters are 147 feet and 88 feet respectively, but weights up to 70 tons may be handled throughout the entire field of operation. This feature of varying the radii at which the hoisting blocks can operate, constitutes a most important difference between the derrick under discussion and the 130-ton steam crane erected in 1893 on Finnieston Quay, Glasgow. In the Finnieston crane, which at time of its construction represented the ideas of best English practice, there is no variation in the radius at which the hoisting blocks are carried, and, in consequence, the field of operation becomes narrowed to a single line, the circumference of a circle described by the blocks on revolving the crane. The advantages of the Newport News derrick are obvious.

The maximum elevations, above mean high water, for the hoisting hooks in the high and lower positions of the jib are 118 and 69 feet respectively; this giving ample clearance vertically for any probable conditions.

Taking up the description of the several parts of the structure, it may be well to follow the actual order of construction and begin with the foundations.

A discussion of the conditions which serve to determine the choice between a masonry or pile foundation is obviously be-

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yond the scope of the present paper, and it is sufficient to say that the decision to adopt a pile foundation was reached, not alone after the possibilities of masonry, but also of metal tubes and cylinders filled with cement, had been investigated at much length. The soil at the point of erection is eminently suited to the use of piles, and it is the author's belief, based on a number of years' experience in that locality, that a properly creosoted pile foundation would, under conditions imposed, have about 90 per cent. of its original strength retained after a period of twenty-five years. Assuming the probable life of the foundation to be twenty-five years, and recurring again to the governing factor of economy, we may, with pertinence, state that the cost of such foundation was about $8,000, and the time consumed in construction about two months; while the masonry foundation for the Finnieston Quay 130-ton crane cost in the neighborhood of $45,000, and required seventeen months to complete. It is apparent that the interest accumulations on the difference in cost for a period of twenty-five years is far more than sufficient to renew foundations and re-erect derrick.

The foundations adopted consist of four concentric rows of piles, driven vertically and spaced 3 feet center to center, measured on the circumference of each ring. One hundred and fifty piles were required for these rings, all carefully selected, straight, round sticks, measuring not less than 14 inches 6 feet from the butt, and not less than 9 inches at the small end. They were carefully treated with London ordinary dead oil, of approved quality, 16 pounds to the cubic foot, and then driven, under a 5,000-pound hammer, to an average depth of 28 feet into the hard bottom of the river. In addition to the above, seventy piles were driven at an angle of 30 degrees to the vertical and secured to the capping by galvanized-iron drift bolts, thus giving the entire foundation greater rigidity and stability. The caps are carefully selected live oak, 14 inches by 11 inches, laid in concentric circles on tops of piles, surmounted in turn by two thicknesses of heavy live-oak flooring, the lower flooring being laid radially across the caps, while the upper one has its lengths laid, similarly to the caps, along the circumferences of concen-

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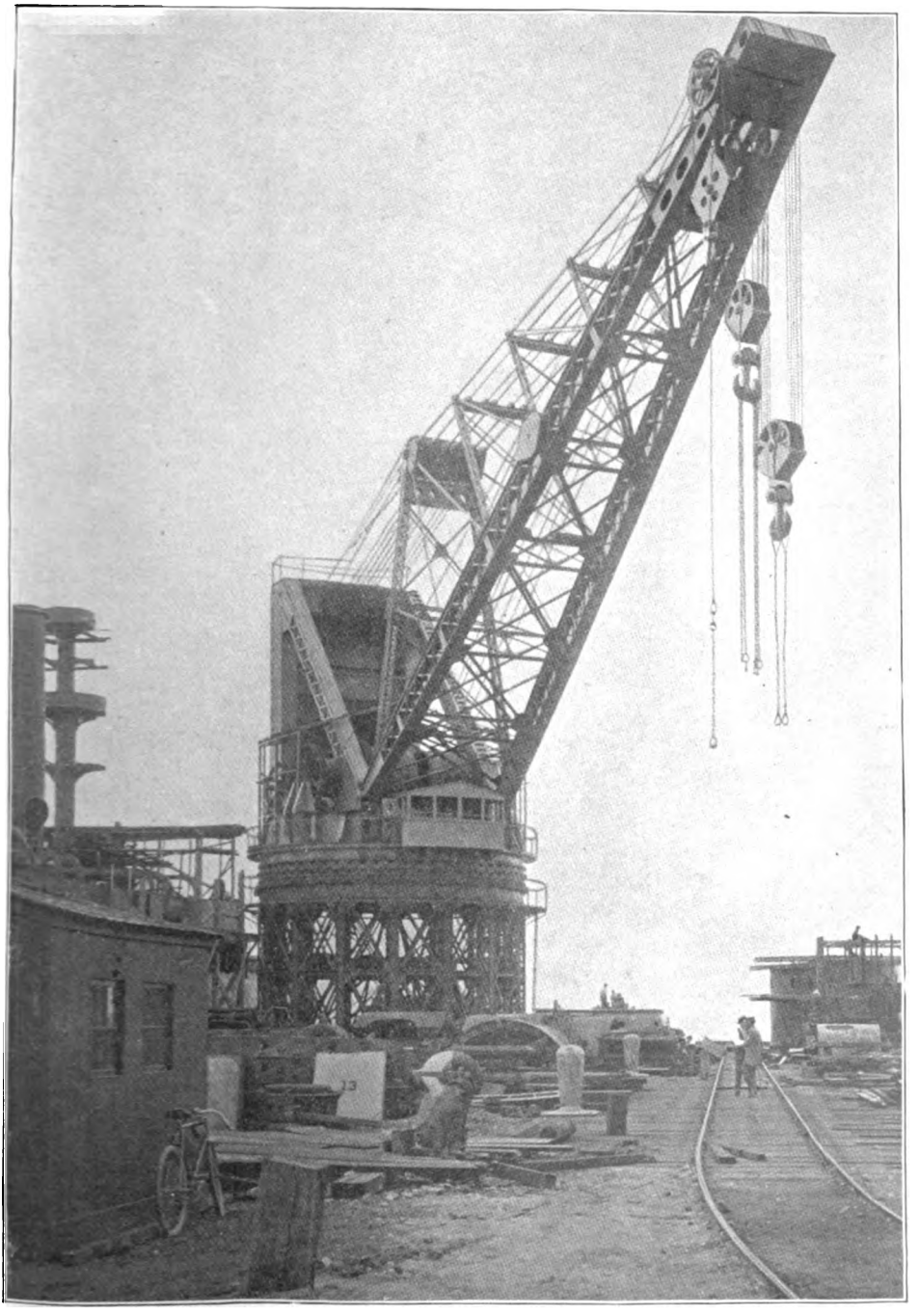

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tric circles. The whole assemblage, of caps and flooring, is protected as much as possible from decay, and firmly secured to the piling by galvanized-iron drift bolts. It may be well to state, as a concluding remark on the pile foundations, that it is intended to fill the pier solidly around the space occupied by the derrick foundations, thus preserving the piling for an indefinite period from the possible attacks of the teredo.

Proceeding to the description of the steel tower: we have a structure cylindrical in general form, comprised of sixteen columns securely braced and anchored, through their shoe plates, to the pile foundations below, the columns being surmounted by a series of box girders to which is bolted the cast-steel track carrying the rollers on which the derrick revolves. The sixteen columns are equally spaced over the circumference of a circle 36 feet diameter and set square to radial lines through their centers. They are built up of two 15-inch channels, 70 pounds to the foot, well latticed on the sides, with batten plates, top, bottom, and midway their height, at which point horizontal and diagonal braces connect. The column shoe plates are seated on iron plates $1\frac{7}{16}$ inches thick, carried by the upper course of live-oak flooring, each shoe being anchored by twelve $1\frac{3}{8}$-inch bolts to the piles, if possible, and where not, to the pile caps.

To heavy box girders, surmounting the columns, are riveted at every other column the ends of lattice girders projecting radially from the center, at which point they connect to heavy gusset plates which serve to build up a central bearing for the 16-inch vertical pin used to center the derrick, and which serves, also, should unforeseen emergency require it, to prevent any lifting tendency of the derrick itself. Projecting outward and downward from the pin bearing, to the base of each alternate column above mentioned, are stiff angle braces, tied at their middle points to the top and middle point of columns by diagonal and horizontal angles. Diagonal tie rods, 2 inches in diameter, running from the top and bottom of the alternate columns, which do not carry radial girders, to the bottom and top of corresponding columns opposite, serve, with the above-mentioned angle braces, to rigidly connect and tie together the whole structure of

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the tower. The circular turned cast-steel track, on which sixty-three conical cast-steel rollers travel, has a mean diameter 36 feet for the roller circle and is so beveled that the top elements of the rollers are always horizontal, thus insuring an easy turning motion. The rollers are held in place by two concentric circular rings, the inner one built up of plates and angle bulb, the outer one of plates alone, these rings being held in place by twenty-one 2-inch steel rods, radiating from the center pin casting, to which they are secured, and passing axially through every third roller and secured at the same time to both roller rings.

We have now reached the revolving structure or derrick proper, which may be, for convenience of description, divided into two members: the housing, a heavily framed structure, containing the generating and controlling machinery, operating platform and counterweight or ballast; to this is secured the second member, namely, the jib, which, carried by the housing and controlled by the power therein, carries in turn the sheaves and blocks through which all the hoisting power must be finally applied.

Recurring to the housing, a brief description will suffice to indicate its general character and note interesting features.

Resting on the conical rollers is a circular girder; on this is carried the heavy cross-girders which furnish supports and foundations for the generating motors, heavy gearing, drums, and other parts of machinery. In a central bearing is the 16-inch pin previously mentioned; at one end of the cross-girders is secured, by a 9-inch pin connection, the lower end of the jib, while at the opposite end of the girders rises the ballast tank containing 410 tons of pig-iron ballast. The ballast tank is built up of heavy floor girders, resting on and running at right angles to the cross-girders above mentioned. From the extremities of these floor girders rise the vertical ends of the tank, each end being a hollow box section and serving to transmit the weight of the ballast from the floor of the tank to the 10-inch pin connections at the top of the tank, from which points inclined struts are run downward and across to the ends of the cross-girders which connect with the lower end of jib. The ballast tank overhangs the circular girder,

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and as only a portion of the weight of the ballast is required to balance the jib in its high position, the remaining weight of ballast is carried, in that case, by the overhanging girders, which are reinforced by brackets on the side.

The arrangement of ballast above described brings the center of gravity of the revolving structure always within a radius of 7½ feet from the center, which, as the path of the roller bearings has a mean radius of 18 feet, gives a minimum factor of stability of 2.4. Thus, with the jib in its highest position and no load, the center of gravity is 7½ feet behind the center, while with 150 tons load at 73½ feet radius, or 70 tons load at 103½ feet radius, the center of gravity is 7½ feet forward of the center. As before referred to, the 16-inch central pin is provided with a top nut and secured below, which thus affords a further safeguard against tilting.

Turning, for a moment, to the jib, attention may be called to the endeavor to so arrange sheaves as to bring the minimum amount of bending and wear upon the pins. The member as a whole is a triangular truss, pin connected and with its long side in compression.

In taking up now the operation of the derrick, we will divide our remarks into three headings, corresponding to the three main movements, namely, revolution, elevation or depression of the jib, and the vertical movement of the hoists.

The derrick is revolved by duplicate sets of machinery, each consisting of one No. 800 General Electric railway motor, capable of developing 20 horse power, and driving, through means of a double-threaded worm and wheel of the Albro-Hindley pattern, a pinion which, engaging a horizontal circular rack on the outside of the tower, gives the required movement of rotation. The motors are series wound and controlled from a series parallel controller, giving high efficiency under starting conditions as well as at normal speed. The turning motion is very smooth and perfectly noiseless, and, as will be seen from the tests, requires very little power.

The racking movement of the jib is effected as follows: At the inner and upper apex of the jib is a 10-inch steel pin carry-

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ing twenty-two cast-steel sheaves, each sheave of 5-foot pitch diameter. At the upper apex of the housing is another 10-inch pin carrying twenty-four similar sheaves. Leading over these two sets of sheaves, and sustaining the weight of the jib and load, are two 1¼-inch steel wire ropes; each rope being wound on alternate sheaves and each end of each rope brought down to separate drums, located below in the housing; this arrangement ensuring freedom from side twisting on the sheaves and also requiring each rope to take its share of the weight. The four drums, on which these ropes are wound, are arranged in pairs, each one of a pair taking opposite ends of the same rope, and each pair driven by a No. 2,000 General Electric series motor of 100 H.P., the power from the motor being transmitted to each drum through a separate train of gears. The drums are of cast iron, 5-foot pitch diameter, carried by 7-inch steel shafts. Each rope, having twenty-two parts, is strong enough to sustain and operate the jib when under maximum load, thus guarding against accident and enabling either motor to be disconnected, and the rope, which it controls, to be removed for repairs or renewal. The motors are series wound, which ensures each taking its proper share of the load.

Passing finally to the hoist, we have two main hoists, each of 75 tons capacity, and one 20-ton whip for lighter loads. The main hoists are each of twelve parts, 1¼-inch steel wire rope, leading over six sheaves, 5 feet pitch diameter, carried on a 10-inch steel pin at the outer end of the jib. The lead from these sheaves to the operating drum is carried down the jib on wooden roller runners. These drums, one for each hoist, are of cast iron, 8½ feet pitch diameter, carried on 7-inch steel shafts, and each driven through a train of gears, by a No. 2,000 General Electric 100-H.P. motor, series wound. These hoists may be coupled together and operated as one hoist of 150 tons capacity. The 20-ton whip is of three parts, 1¼-inch steel wire rope, carrying a single block and leading over two sheaves, carried, as are those for the main hoist, at the outer end of jib. The lead from these sheaves passes down the jib, over a single guide sheave, to a cast-

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iron drum, 8½ feet pitch diameter, driven through a train of gears by a No. 2,000 General Electric 100-H.P. motor, series wound.

It will be noticed that electricity is used to generate the power required for all the movements of the derrick. The question involved in the choice as to the form of energy to be employed in such a machine cannot be fully discussed here, but the convenience of operation, ease of movement, and general efficiency of the present derrick attest the successful use of electricity in this case. Current is transmitted, over heavy, insulated copper wire, to fixed brushes, attached at the center and near the top of the steel tower. These brushes are arranged to bear against circular contact rings insulated from, but carried by, the center casting to which the roller rods are secured. Near the top of this casting are two more contact rings which transmit the current to a pair of brushes, fixed to the revolving part of the derrick, from which the current is delivered over heavy, insulated copper wire to the several motors. The current is delivered to the motors, under normal conditions, at a pressure of 220 volts.

Before concluding, it may be interesting to note a few particular features, and to give the result of such tests as opportunity has permitted up to the present time.

The brakes are a feature of considerable interest. These were required to occupy little space, be powerful and certain in their action, and to be automatic. This was accomplished by extending the ordinary band brake so that it wound four and one-half times around a brake cylinder carried on the shaft to which is keyed the pinion that meshes into the gear of the operating drum. This brings the brake in as direct connection with the load as possible and guards against accidents of the machinery. The brake cylinders are of cast iron, 30-inch diameter, with the wearing surface chilled. The band is of wrought-iron, 1 inch thick, 5 inches wide at one end, and tapering to 1¼ inches at the other. The broad end is firmly anchored, while the narrow end is secured to a lever carrying a weight of 200 pounds. When lowering the jib or the hoisting blocks, the direction of rotation for the brake cylinders is toward the small end of the band, so that the friction, produced by the weight, between the cylinder and

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TESTS OF THE 150-TON ELECTRICALLY-OPERATED JIB CRANE AT NEWPORT NEWS SHIPYARD.

MOVING JIB.

Movement.	Net load.	H.P.	Time.
			minutes.
From lowest to highest position	0	89.0 to 64.1	6.9
From highest to lowest position	0	0. 0.	5.56

HOISTS.

Hoist.	Net load.	Speed in feet per minute.	H.P. delivered to motor.	H.P. required to hoist load.	H.P. absorbed by machinery.	Efficiency.
	long tons.					*per cent.*
Right-hand main	68	6.05	54.3	28.0	26.3	51.5
Right-hand main	0	10.12	29.2	0	29.2	0
Left-hand main	66	7.03	61.9	31.4	30.5	50.9
Left-hand main	0	9.08	30.65	0	30.65	0
Whip	19.2	52.3	88.9	68.3	20.6	76.8
Whip	0	84.3	35.35	0	35.35	0

REVOLUTIONS.

No. of test.	Net load.	Total weight on rollers.	Center of gravity from center of revolution.	Time of one revolution.	H.P. delivered to motors.
	long tons.		*feet.*	*minutes.*	
1	134	910	4.28	3.38	10.71
2	68	845	2.22	3.36	11.17
3	0	775	1.47	3.04	11.15
4	0	775	7.00	3.04	11.15
5	0	775	4.49	3.55	10.65

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band, causes the band to wind tight on the cylinder and stop rotation. In hoisting, the brake releases itself, the friction lifting the weight and uncoiling the band, while any tendency to rotate in the opposite direction causes the weight to fall and the band to tighten. To release the brake it is only necessary to lift the weight, which is done by means of a wire connecting with a lever in the operating house, the lever being always within reach of the operator, and the brakes always in operation except as released by continuous pull on the lever.

The operating station is directly underneath the lower end of the jib, overlooking directly the weights to be handled, and encased with glass front as a protection against the weather. The controllers for the several motors are within easy reach of a single operator, who is thus given convenient and absolute control over the varied movements of the derrick. The ropes for the hoist and racking movement are all of plow-steel wire, 1¼ inches in diameter, of six strands of thirty-seven wires each, with hemp center and very flexible. Each rope has a breaking strength of 100,000 pounds. The gears throughout, except the worms and those supplied with the motors, are of cast steel with cast teeth, the pinions being full shrouded. These gears work very smoothly and show a high efficiency.

The difference in power required for the two main hoists is explained by the fact that all gears, except the pair on motors, have cast teeth and, consequently, variable friction. All tests were made soon after the completion of the derrick, and still better results may be anticipated when opportunity has been given for the gears to wear smooth.

The jib has been both raised and lowered with loads up to 66 tons, but, as this was done only in regular course of work, no data was taken. In hoisting, the required power decreases as the moment of the jib decreases. In lowering, power is required to start the machinery, after which the weight of the jib will keep it in motion.

The variation in speed and power required was probably due to influence of the wind, as the observations were taken on different days, with different velocities of the wind. Tests Nos. 3 and

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4, taken as near as possible, show no difference in result, although the position of the center of gravity varied considerably.

The safety factors attained in the various members are as follows:

Lower struts or legs,	10
Tension members—eye bars,	9
Inclined struts,	7
Wind bracing,	12
In hoisting ropes,	7
In tower columns,	7.5
In tower wind bracing,	15

The total weights in long tons are as follows:

Derrick on rollers (no load),	775
Derrick on rollers (maximum load),	925
Entire structure on piles (no load),	926
Entire structure on piles (maximum load),	1,076
Maximum load for piles, taking vertical piles only and considering eccentricity of loading,	9.04

A brief summary of tests is given in table.

In concluding this paper it may be said that the most difficult problem encountered, in the design of the derrick, was that of providing a safe and efficient way of operating the jib, and in so far as the author knows, the method adopted is, considering the large forces involved, something of a novelty. The results attained and the efficiency of the mechanism would indicate that the problem had been well solved, and that the idea here carried out might, with advantage, be extended by other designers to future problems.

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MACHINE SHOP NEW YORK NAVY YARD. VIEW FROM EAST GATE.

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NOTES.

THE DESTRUCTION OF THE MACHINE SHOPS OF THE NEW YORK NAVY YARD BY FIRE.

The machine shops of this yard were totally destroyed by fire between the hours of 6 and 10 P. M., February 15, 1899. The building is a three-story structure, brick and granite walls, the first and second floors being occupied by machine shops and the third floor by the pattern shop.

The fire seemed to originate in the office on the second floor, and spread all through that floor with extraordinary rapidity. The city fire department responded as promptly as possible with twelve engines, one water tower, the fire boat *Seth Lowe*, and four hook and ladder companies. Great difficulty was experienced in getting engines and hose in place owing to deep snow on the vacant ground leading to hydrants. Here very valuable assistance was rendered by relief parties from the *Massachusetts*, *Vermont*, *New Orleans*, *Newark* and *Supply*, and by the yard stable force and horses. The yard officers and naval employees were on the ground and gave valuable assistance. With great difficulty the foundry on the opposite side of the street from the machine shop was saved. The walls of the main building fell, but the corner towers remained standing. The boiler shop was only slightly injured, and the power-house boiler room was saved. A horizontal engine used for running the dynamos was saved, although the falling walls ruined the dynamos themselves. As there was a line of shafting from over this engine leading to the boiler shop, it was possible to belt up and run this engine by the 18th for driving the tools in the boiler shop.

The east wing, which was used as an erecting shop, was considerably damaged. All the machinery and tools in the main shop were ruined.

An estimate made on the loss of the buildings, which merely indicates the book cost of the original buildings with improve-

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ments, and not that which is necessary for replacing, was as follows:

Main building,	$621,496
Boiler-shop wing,	5,000
Erecting shop,	2,000
Boiler house,	1,800
Office building,	300
Electric-light plant,	3,200
Cost to clear site,	7,000
Total,	$640,796

Plans are being prepared for the erecting of new shops, the front wall to be on the line of that of the original shop, but the front building to be 130 feet wide, the east wing to be 130 feet wide also, and the west wing to remain same width as it now is, which is approximately 90 feet, and both wings to be extended 160 feet farther than the original lines. This, with modern tools and electric traveling cranes, will probably be the finest machine shop in the world.

INVESTIGATIONS OF A BLOWING FAN.

During the last three years Professor Carpenter, of Cornell University, has been making investigations of fans, and at the annual meeting of the American Society of Heating and Ventilating Engineers, held last month in New York city, presented the principal conclusions he had reached, in a paper under the above heading, the "Engineering News" of February 2d, 1899, thus summarizes the results:

The first investigation established the following propositions, which were advanced some years ago by Murge.

First. The volume of air delivered varies as the speed of rotation.

Second. Difference of pressure varies as the square of the speed.

Third. The power required varies with the cube of the speed.

The object of the later investigations was to determine the

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most efficient form of fan blade, and also the effect due to variation in size of outlet and inlet. For the purpose of testing fans with different shaped blades, the radial blades were removed and bent blades substituted, which were radial for a distance of 7 inches, then curved in an easy bend in a direction approximating tangential at the outer extremities. The bent blades were arranged so that they could be operated with the curved end run in a backward or forward direction. The area of the plane blades in the direction of the radius was 1.5 square feet, the projected area of the curved blades on a radial plane was 1.37 square feet. As compared with the radial blades there was a loss in quantity of air delivered for a given rotative speed of nearly 25 per cent. when the blades were bent backward, and but little loss when the blades were bent forward. As normally constructed there was but one inlet to the fan, which was 22 inches in diameter. For a portion of the experiments a second inlet of the same size was constructed on the opposite side, so that experiments were made with the radial blades with two inlets.

Relation between horse power delivered to fan and outlet area: The blades bent backward take the smallest amount of power for a given outlet; the radial blades an intermediate amount and the blades bent forward the greatest amount. The power required for the radial type of blades for very small openings was decreased, but for larger openings was increased by doubling the inlet opening, which effect is accounted for by noting that the quantity of air delivered is greatly increased for the larger openings.

Relation between the quantity of air delivered in cubic feet per second and the area of outlet opening for a constant speed of 500 revolutions per minute: With a single inlet opening the greatest quantity of air for a given outlet area was obtained with the fan which had the blades bent forward, the amount delivered by the radial blade being intermediate, that by the blades bent backward the least. The effect of doubling the inlet area was to increase the quantity of air delivered by the radial fan very materially for the larger openings.

Variation in the quantity of air delivered per horse power in cubic feet per second due to changing area of the outlet, and

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consequently the back pressure: The best results were obtained from the fan with blades bent backward. Rounding off of the tips of the blades and bending them backward decreases the amount of air delivered, and also the power required to drive the fan, as compared with the other conditions, but the power required to drive the fan is reduced more than the delivery of air, consequently the air delivered per horse power is the greatest, or, in other words, the efficiency of this type of fan is the greatest of the types compared under the same condition of inlet. Doubling the area of the inlet, for the fan with radial blades for a small area of outlet or for back pressures much exceeding one inch of water, made no special change in the results, but for large area openings or when the pressure is less than about one inch of water, much more air is delivered.

Relation between the velocity of delivery, the back pressure and the area of outlet: For the two conditions of the radial blades and blades bent forward, the velocity of the discharge exceeds the peripheral velocity of the fan when the back pressure corresponds to about 1.6 inches for the case considered. For a higher or a lower back pressure the velocity becomes less.

The type of blade which gives the lowest velocity of air gives the best result as to the quantity of air per horse power, from which it would appear that the most effective fan is the one which delivers the air at the lowest velocity. With the type of blade bent backward at the tips, the maximum velocity lacks 11 feet per second of reaching the peripheral velocity of the fan; the other three types exceed the fan velocity at the maximum point, as already mentioned. It is probable that the reason why the blades bent backward do not give so high a velocity is due to the slipping of the air over the tips of the blades.

Relation between efficiency of the fan, the area of outlet in square feet and the pressure produced by the radial type of fan: Each type of fan has a condition of maximum efficiency with constant speed which occurs under the condition of the test with the fan with blades bent forward when the back pressure is about 1.7 inches of water, for the fan with the radial blades when the pressure is about 1.5 inches, and for the fan with blades backward

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when the pressure is about 1.4 inches. The fan with the blades bent backward has a maximum efficiency of about 43.5 per cent.; the fan with the blades bent forward has a maximum efficiency of 37 per cent., and with the radial blades a maximum efficiency of about 33.6 per cent. The fan with the radial blades double inlet had a maximum efficiency of about 45 per cent. which occurs, however, with a low pressure of air.

Relation between pressure in delivery box and the area of outlet, when the fan is working at a constant speed: The fan with blades bent forward gives the highest pressure, and the fan with blades bent backward gives lowest pressure, but for openings of the delivery tube much in excess of the area of the blade, the fan with the double inlet shows the greatest pressures. In all cases that the pressure is greatest when the delivery of air is least. Buckle* gave as results of his experiments the following formula for expressing the relation between the pressure produced and the peripheral speed, as reduced by Kent in his "Pocket Book for Mechanical Engineers:"

$$v = 60\sqrt{p}$$

in which p is the pressure expressed in inches of water and v is the peripheral velocity of the fan in feet per second. The pressure deduced by Buckle's formula would be obtained under conditions like those in the experiment cited when the area of discharge opening expressed in percentage of the area of the blade was 15 per cent. when the blades were bent backward, 18 per cent. when the blades were radial, and 25 per cent. when the blades were bent forward.

I have found by a comparison of Buckle's formula as above with actual tests that the maximum pressure which is produced by a given peripheral velocity is greater than that stated by Buckle by an amount which varies in different conditions from 1 to 15 per cent. The maximum pressure which may be produced is the only one which can be considered as positively depending upon the peripheral velocity, since the actual pressure in any given case depends very largely upon the resistances

* Paper before Institute of Mechanical Engineers, England, 1847.

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to a free discharge corresponding in the case of the experiments cited to the area of outlet. The more freely the air is discharged, or, in other words, the less resistance, the less the pressure that will be produced by the fans. Buckle's formula, however, is usually a safe one to employ, since the pressure given by it is less than can be realized in practice, provided the resistance to the flow of air is at a maximum.

SHIPBUILDING AT NAGASAKI.

The "Marine Record" publishes the following notes communicated by Charles B. Harris, Consul at Nagasaki, Japan.

There has recently been delivered to the Nippon Yusen Kaisha what is said to be the largest steamship that has ever been launched outside of American or European waters.

The vessel is the *Hitachi Maru*, built to order by the Mitsu Bishi Company in its shipbuilding yards at this port. She was about twelve months in the builders' hands, and before delivery to owners was subjected to survey by an officer sent especially from London. Her class is Lloyds' 100 A1, approved by the shipbuilding encouragement law of the Imperial Japanese Government; type, 3 decks; material of hull, steel; length, 462 feet; beam, 49 feet 2 inches; depth, 33 feet 6 inches; draught, average, 25 feet; gross tonnage, 6,150 tons; displacement, 11,660 tons; freight capacity, 7,150 tons; engines, triple-expansion, double screws; boilers, 4; indicated horse-power, 3,500, speed, 14 knots.

The Mitsu Bishi Company will immediately commence the construction of a sister ship to the *Hitachi Maru* for the Nippon Yusen Kaisha.

There has also been opened at this port by the Mitsu Bishi Company a new granite dock, of an extreme length of 371 feet; length on blocks, 350 feet; breadth, 78 feet, with draught of 23 feet at high water. This dock is close to the engine works of the company, which have been largely improved by the extension of the buildings and by the addition of machines of the latest type, including a large overhead crane of 30 tons carrying power

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in the erecting shop and new sheer legs of 80 tons capacity on the jetty for the landing and delivery of heavy boilers and machinery. The boiler shop, with its 105-ton riveting machine and other appointments, is now equal to the heaviest kind of work. A powerful steam hammer has been added, as well as other improvements necessitated by the increasing requirements of vessels and the larger type of ships now navigating the eastern waters. Rails have been laid from the sheers to and around the works with turntables, etc. A new molding shop of 50 tons capacity, with all the modern improvements, has been erected.

The ship-building yard has been laid out for vessels up to 500 feet in length, and ground enough has been added for four vessels to be on the stocks at one time. Ships of 300 to 450 feet are now being built. The molding loft, with carpenter shops underneath, has been greatly increased in size.

The No. 1 dock has been lengthened so that it can now take in vessels of the heaviest draught, up to a length of 500 feet; while the patent slip and siding can take vessels of over 1,000 tons register. The docks will accommodate five vessels of ordinary size at one time.

The Mitsu Bishi Shipbuilding Company, when busy, employs 2,000 men; it pays laborers 60 sen a day, which is 30 cents gold; skilled workmen receiving from 1 yen (50 cents) per day upwards. This company is gradually advancing the pay of employees, for the reason that the cost of rent, fuel, clothing and food to all classes has so increased as to render an advance necessary. The cost of living among all classes has increased enormously at this port—entirely out of proportion to the advance in wages and salaries.

TRIPLE-SCREW WAR STEAMERS.

It is doubtful if any of the new vessels afloat in other navies ever developed the same steaming qualities as the *Minneapolis* when she made over 24 knots on part of her official run between Boston Bay and the Maine coast. The *Kaiserin-Augusta* and the *Gefion* have triple screws and were built about the same time, both capable of about 24 knots. Germany is building seven new

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vessels of the *Freya* class, all of which are to have three screws. Each ship is to displace 5,650 tons, have a sustained speed of at least 20 knots on a horse power of 10,000. They will all be cruisers. A larger vessel is the armored cruiser *Fürst Bismarck*, which is to have three screws, and is designed for a displacement of 10,600 tons, a horse power of 13,000, and is expected to make 19 knots with each. None of these vessels seem deserving of being classed with the *Minneapolis* and *Columbia*, which have for years been considered the fleetest war vessels of their displacements in the world. France is building five battleships which are to have three screws, three of which are to be like the *Charlemagne*, her most powerful class, and will be ready for service shortly. The *Charlemagne* and *Saint Louis* are regarded by the experts of France as the best type of battleship building for the navy, and the success of the three-screw system in ships of such great displacement is awaited with some anxiety by her experts, who have not had full confidence in it. The displacement of these ships is 11,275 tons each, horse power 15,000, and a speed of 16 knots. They are to have the same speed with three screws that the new battleships recently contracted for by our Navy Department are required to develop with twin screws.

Two other battleships, of the *Henry IV* class, are also building and will be fitted with triple screws. These are of 9,000 tons displacement, 11,500 horse power and a speed of 18 knots. Ten armored cruisers are either building or practically completed, which are all to have triple screws, high speed and enormous steaming radius, and be in all respects equal to the best of their type in the world. The *Jeanne d'Arc* will be the best of these vessels and perhaps the most formidable if not the fleetest armored cruiser in the world, equaling the immense vessel of this size lately turned out by British shipyards. This new French vessel is to have a displacement of 11,270 tons, or about equal in size to the American battleship *Iowa*, but her horse power is to be at least 28,500, or 11,000 greater than that of the *Columbia* or *Minneapolis* and three times that of the *New York*. A speed of 23 knots is expected, and if she equals this the *Minneapolis* will have her first rival. Six vessels of the *Montcalm* class and also

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of the armored cruiser type are building with three screws, on displacements of 9,517, horse power of 19,600, and a speed of not less than 21 knots. Three more armored cruisers of the *Desaix* class are also under construction with triple screws, each to be of about 7,700 tons displacement, 17,000 horse power, and a speed of 21 knots.

In addition there will be two commerce destroyers, the *Chateaurmenault* and *Guichen*, of displacements of 8,300 tons, horse power of 24,000, and a speed of 23 knots. These are in many respects similar to the *Minneapolis* and *Columbia*, although larger and with greater machinery power. They are expected by the French designers to be the fastest vessels of the navy outside of torpedo boats. Russia is also building large warships with three screws. Two of these are battleships, the *Oslabya* and *Pereswich*, which are designed to be her most formidable warships, and are expected to be the fleetest afloat. These vessels as contracted for are to be of 13,560 tons and 14,500 horse power, which it is believed will give them a speed of about 20 knots. Another immense vessel building with three screws is to have a displacement of 14,000 tons and a speed of 23 knots. She is said to be of the commerce-destroyer type, although the Navy Department has no official description of the vessel. Four other ships are also building, of the *Diana* class, to have displacements of 6,500 tons, 11,000 horse power, and a speed of 21 knots.—"American Shipbuilder."

EXPERIMENTS ON THE FLOW OF STEAM THROUGH PIPES.

At the December meeting of the American Society Mechanical Engineers in New York Professor R. C. Carpenter, of Cornell University, presented an interesting and valuable paper on the above subject illustrated by a series of tables, one of which is here reproduced, showing the delivery in pounds per minute by pipes of given lengths and diameters, taking an absolute pressure of 100 pounds as initial standard and allowing a drop of only one pound. It affords a ready method of closely approximating pipe sizes in getting up pipe plans for steam plants, as well as for criticising existing lines of piping.

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FLOW OF STEAM IN PIPES. DELIVERY IN POUNDS PER MINUTE BY PIPES OF GIVEN DIAMETERS AND LENGTHS.

(Absolute pressure, 100 pounds; drop in pressure, 1 pound.)

Calculated by E. C. SICKLES.

Diameter in inches.	Length in feet.																							
	25	50	75	100	125	150	175	200	225	250	275	300	325	350	375	400	425	450	475	500	525	550	575	600
¾	2.20	1.55	1.27	1.10	.983	.898	.831	.700	.733	.698	.659	.633	.611	.589	.568	.550	.532	.518	.506	.491	.481	.468	.457	.450
1	4.40	3.10	2.54	2.20	1.96	1.79	1.66	1.55	1.46	1.39	1.32	1.26	1.22	1.17	1.13	1.10	1.06	1.03	1.00	.982	.962	.932	.914	.900
1¼	9.76	6.90	5.63	4.88	4.36	3.93	3.69	3.44	3.26	3.08	2.92	2.81	2.72	2.62	2.52	2.44	2.36	2.29	2.24	2.18	2.13	2.07	2.03	1.96
1½	13.04	9.29	7.64	6.52	5.83	5.83	4.95	4.62	4.35	4.14	3.92	3.77	3.62	3.50	3.36	3.26	3.16	3.07	3.00	2.91	2.85	2.77	2.72	2.67
2	30.54	21.6	17.6	15.2	13.6	12.50	11.58	10.8	10.2	9.82	9.32	8.82	8.40	8.37	7.87	7.63	7.40	7.18	7.01	6.81	6.68	6.51	6.36	6.23
2½	50.8	35.9	29.3	25.4	22.7	20.8	19.2	17.9	16.9	16.2	15.2	14.62	14.4	13.6	13.1	12.7	12.3	11.9	11.6	11.3	11.0	10.7	10.5	10.4
...	50	100	175	250	325	400	475	550	625	700	775	850	925	1,000	1,075	1,150	1,225	1,300	1,375	1,450	1,525	1,600	1,675	1,750
3	65.17	46.0	35.0	29.2	25.6	23.0	21.2	19.6	18.4	17.4	16.5	15.8	15.2	14.5	14.0	13.6	13.1	12.7	12.4	12.10	11.82	11.5	11.2	11.0
3½	98.3	69.5	52.7	44.6	38.6	34.7	31.9	29.6	27.7	26.3	24.92	23.8	22.8	22.0	21.3	20.5	19.8	19.2	18.6	18.2	17.8	17.4	16.9	16.6
4	138.1	97.6	73.8	61.8	54.2	48.8	44.8	41.5	39.1	36.7	35.0	33.5	32.1	30.8	29.8	28.7	27.8	27.1	26.3	25.6	25.0	24.4	23.8	23.3
4½	187.9	132.9	102.0	84.1	73.8	66.45	61.2	56.6	53.1	50.1	47.7	45.6	43.7	42.0	40.51	39.2	38.0	36.75	35.75	34.75	34.0	33.2	32.4	31.8
5	255.6	180.7	136.2	114.3	102.2	90.3	83.3	76.9	72.1	68.2	65.1	62.1	59.6	57.1	55.1	53.2	51.6	50.0	48.6	47.2	46.3	45.2	44.2	43.2
6	419.4	296.5	224.1	187.2	164.2	148.2	136.1	125.8	118.4	111.8	106.8	101.8	97.3	93.7	90.2	87.2	84.2	82.2	79.7	77.6	75.7	74.1	72.2	71.0
...	50	100	175	250	325	400	475	550	625	700	775	850	925	1,000	1,075	1,150	1,225	1,300	1,375	1,450	1,525	1,600	1,675	1,750
7	618	437	330	276	242	218	200	186	174	165	157	150	143	138	133	129	125	121	118	115	112	109	107	104
8	890	624	472	394	346	312	286	266	249	236	224	214	205	197	190	184	178	173	168	164	160	156	152	149
9	1,206	853	644	539	473	426	391	363	341	322	306	292	280	260	260	251	243	236	230	224	218	213	208	204
10	1,592	1,126	851	712	624	563	516	480	450	425	404	386	370	356	343	332	321	312	303	295	288	281	275	269
11	2,046	1,447	1,093	915	803	723	664	617	574	546	519	496	476	457	441	426	413	401	390	380	370	361	353	346
12	2,575	1,887	1,428	1,192	1,044	943	852	803	752	714	679	648	620	598	575	557	539	523	509	494	487	472	461	451
13	3,165	2,238	1,692	1,415	1,242	1,119	1,027	954	891	846	804	767	736	707	682	660	639	620	603	588	573	559	547	535
...	50	100	200	300	400	500	600	700	800	900	1,000	1,100	1,200	1,300	1,400	1,500	1,660	1,700	1,800	1,900	2,000	2,100	2,200	2,300
14	3,838	2,714	1,920	1,567	1,357	1,213	1,108	1,025	959	904	858	818	783	752	725	700	678	658	639	622	606	592	578	566
15	4,596	3,250	2,300	1,873	1,625	1,453	1,377	1,228	1,149	1,083	1,028	980	938	901	868	839	812	788	766	745	726	709	693	678
16	5,630	4,000	2,830	2,315	2,000	1,785	1,638	1,513	1,413	1,333	1,268	1,208	1,153	1,108	1,072	1,034	1,000	972	945	916	895	834	854	834
17	6,375	4,500	3,210	2,635	2,250	2,021	1,841	1,702	1,591	1,500	1,424	1,357	1,302	1,248	1,200	1,162	1,124	1,087	1,061	1,033	1,006	982	962	940
18	7,370	5,211	3,685	3,008	2,605	2,330	2,128	1,970	1,843	1,737	1,648	1,571	1,504	1,445	1,393	1,345	1,302	1,264	1,228	1,192	1,165	1,137	1,111	1,087
19	8,472	5,992	4,237	3,459	2,996	2,680	2,447	2,265	2,119	1,997	1,895	1,807	1,730	1,662	1,602	1,547	1,498	1,453	1,412	1,374	1,340	1,307	1,278	1,249
20	9,240	6,838	4,835	3,948	3,419	3,059	2,793	2,585	2,418	2,279	2,163	2,062	1,974	1,897	1,828	1,766	1,709	1,658	1,612	1,569	1,529	1,492	1,458	1,426
22	12,365	8,743	6,183	5,048	4,371	3,910	3,570	3,278	3,093	2,914	2,765	2,627	2,524	2,406	2,337	2,257	2,185	2,121	2,061	2,005	1,955	1,908	1,864	1,823
24	15,943	11,308	7,990	6,535	5,650	5,065	4,522	4,435	3,995	3,769	3,580	3,418	3,271	3,141	3,023	2,921	2,820	2,750	2,665	2,585	2,535	2,472	2,415	2,361

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THE PURCHASE OF SECOND-HAND BOILERS.

"Engineering" of December 9, 1898, notes the following conditions in England surrounding the matter of sale of second-hand boilers:

The Board of Trade investigation regarding the recent boiler explosion at Norwich, again draws attention to a matter of importance not only to steam users, but to the general public. From time to time we have reported the occurrence of explosions from miserable little boilers fit only for the scrap heap, but which have been sold and resold, with an utter disregard of the fact that they were dangerously defective, and that on being set to work they might explode at any moment with the most serious consequences. Given a practically worn-out boiler, a broker desirous of effecting a sale, and a purchaser on the look out for a cheap bargain, and too ignorant or too penurious to have an examination made to ascertain whether or not the boiler he proposes to purchase is safe to work, and we have all the essential elements of mischief. This has occurred on various occasions, as shown by the Board of Trade official reports, and the danger apparently remains as imminent to-day as it did when the Boiler Explosions Act was instituted, notwithstanding the fact that in several instances brokers and purchasers alike have been censured, and mulcted in penalties at the formal investigations.

We have from time to time met with many cases in which worthless boilers have been purchased at second, third or fourth hand; and, whatever the brokers may have known, the purchaser has been entirely ignorant of the danger that existed, although probably the low price that he paid should have given him warning and led him to suspect that all was not right.

Some time ago a boiler of weak and antiquated construction, which had seen long service and certainly deserved oblivion, was condemned by an examiner of undoubted ability, and was pulled out and sold to a dealer in machinery. The dealer did not cut it up; far from it, but he gave it a coat of paint, put in a few new rivets here and there, and sold it to a respectable shipping firm, who set it neatly in brickwork at the basement of their

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large warehouse, situated in the heart of a populous city. An insurance company was called in to make an examination before starting work, and the inspector at once recognized in the boiler his old acquaintance which he had condemned some months previously, but which had been purchased by the new firm, doubtless in the belief that they were getting a serviceable article. Needless to say, the boiler was again condemned, and was removed by the broker who, on an action at law being threatened, returned the purchase money. This is by no means a solitary case, and others have occurred in which the danger has not been revealed until too late for a remedy.

The explosion at Norwich is an illustration of the unfortunate carelessness which too often accompanies the transaction of buying second-hand boilers. A Manchester contractor was in want of a boiler to drive a mortar mill in connection with the erection of a new technical school at Norwich, the Corporation having accepted his tender. Seeing an advertisement in which a boiler and a mortar mill, described as "strong" were offered, he corresponded with the firm who had them on sale, and at length became the purchaser. They were brought to Norwich, and on the first day steam was got up the boiler exploded, killing a lad and injuring several other persons.

The boiler, which was stated to be of considerable age, was a small one of vertical construction. The crown of the fire box was not efficiently tied to the crown of the shell, as is usually the case, by an uptake or other means, inasmuch as the gases after leaving the fire box passed into a smoke box at the back and thence to a chimney. Apparently through weakness the crown of the fire box had bulged downward some 4 inches or 5 inches, and this defect was noticed by two or three of the men who were engaged in coupling the boiler to the engine, and who stated at the official investigation that they duly reported the fact to those most concerned. No notice, however, appears to have been taken, and the warning passed unheeded. It is true that a water pressure of 100 pounds was put on with a view, it was stated, "of detecting leakage," but no examination of the fire box was made either before, during, or after the test, so that was utterly worth-

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less and possibly misleading. When set to work, the boiler gave a practical protest by bursting; the weak fire-box crown collapsed, with the serious results we have mentioned. The surveyor to the Board of Trade informed the Commissioners that the pressure at which the boiler exploded was 95 pounds, and that had it been submitted to examination by the Board of Trade "it would not have been passed to work at any pressure whatever." The purchaser endeavored through his counsel to convince the court that when he saw the word "strong" used in the advertisement, he took it to apply to the boiler. The broker, on the other hand, said it only applied to the mortar mill, and that it was the duty of the purchaser to have the boiler examined and to assure himself of its safety. After an exhaustive inquiry lasting three days, the presiding commissioner took the broker's view of the matter, and practically exonerated every one except the purchaser, who had, he said, displayed great negligence in not having an inspection of the boiler made by a competent person. The purchaser was, he said, seriously to blame, although he had not acted from any unworthy motive, and he was ordered to pay the sum of £100 toward the costs of the investigation.

We accept this ruling, and are quite prepared to believe that both the seller and the purchaser were unaware of the dangerous condition of the fire-box crown. But we submit that ignorance is by no means a valid excuse, that both parties were seriously to blame, and that both should have shared the penalty. A broker, even in ignorance, has no moral right to sell to a purchaser, equally ignorant and careless, an article which, on being used, may fail, and deal death and destruction around. The broker in this case displayed great earnestness and shrewdness in urging on the purchaser that he would get a good bargain, as the mill was a very strong or "heavy" one. How was it, then, that he had been so lamentably careless in buying so defective a boiler, and subsequently offering it for sale in its dangerous condition, without any examination, without a word being said as to the fitness to drive the "heavy" mortar mill, and without advising the purchaser to make his own examination and obtain his own guarantee of safety? One would

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have thought that common sense would have led the broker, and also the purchaser, to ascertain beyond all doubt that the boiler was fit to effectively drive the "strong" mill, which, being admittedly heavy, would naturally require a fair pressure of steam. But there was no common sense in the transaction; the question of safety or of a safe working pressure does not appear to have been considered, and the fact that the mortar mill was a strong one monopolized the attention of the parties.

The case seems to be full of unintentional misleading and misunderstanding, but the purchaser has had to pay dearly for the omissions of which he was guilty. In future those who contemplate buying second-hand boilers would do well to remember that, according to the ruling above stated, the onus of proof of safety rests upon themselves. By the judgment of the Board of Trade Commissioners just given it would appear that a broker offering for sale a defective boiler may, by showing that he was ignorant of danger, and that it was the purchaser's duty to satisfy himself that the boiler was safe, is relieved of responsibility, and practically acquitted of blame should an explosion occur. This may be good law, but some people may think it is bad justice. In some previous Board of Trade investigations brokers have been censured for selling unsafe boilers, and have had to pay a portion of the costs. This, we think, is but fair. Where so important an apparatus as a steam boiler is concerned, on which so much depends, there should be intelligence and care on the part of the salesman as well as on the part of the purchaser. If brokers wish to relieve themselves of responsibility, it would be well, when offering boilers for sale, to plainly tell their customers that they give no guarantee that the boilers are safe, but that they must look to this point for themselves by calling in a competent authority to make an effective examination.

The question of compulsory inspection has for the present apparently gone to sleep, but it certainly is a matter for regret that worn out and dangerous boilers can be sold and bought without let or hindrance, and set to work by anyone and any where, and in close proximity to crowded streets or important public buildings. If Parliament cannot take the matter up, what is there to

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prevent our town or district councils, with whom rests the responsibility for the erection of buildings within their jurisdiction, passing a rule or by-law requiring that any steam boiler put up in connection therewith should possess a certificate of safety granted by some examiner recognized as competent? This, we think, would only be a reasonable precaution, and would tend to reduce the risk of a repetition of the Norwich explosion.

Meantime it rests with the Board of Trade to consider the question whether the end in view may not be assisted by making ignorant or careless brokers, who have sold boilers which have subsequently exploded, share the official censure and the costs of the formal investigations along with the purchasers. It is wonderful how ignorance is sometimes dispelled when the pocket is approached, and if a few careless salesmen were heavily fined, as well as the equally careless people who buy their wares without the necessary inquiry and inspection, it is very probable that under a sense of increased responsibility greater care would be taken by all concerned in such transactions.

INCREASE OF THE STRENGTH OF STEEL A FEW DAYS AFTER MANUFACTURE.

In the discussion of Mr. W. R. Webster's paper on Specifications for Structural Steel and Rails, read before the Franklin Institute, Mr. A. A. Stevenson, of the Standard Steel Company, Burnham, Pa., gave some interesting results of tests showing that the strength of railway tire steel is increased by allowing a few days time to elapse between the time the product is finished and the tests are made. We quote from the Journal of the Franklin Institute of January, 1898:

"You state that 'the quality of steel depends (1) on its chemical composition: (2) on the treatment it received in the course of manufacture.' I would go a step further, and say that, in my opinion, as far as open-hearth steel is concerned, the physical results, to a certain extent, depend on manipulation of the bath in the furnace.

"Concerning the relations between the chemical composition

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and physical results, I must say I have been somewhat surprised to find how close this relation is. The point in question has been brought out strongly in test work we have recently done on some tires made for a foreign government to a rather difficult specification.

"I heartily agree with the effort to have the conditions under which tests are made reduced, as far as possible, to a standard. In my own experience, I have found a great many tests that were practically valueless for comparative purposes on account of unknown or varying conditions.

"I think it is desirable not only to have dimensions of test piece and pulling speed standard, but also important to have a record of the period elapsing between the time the product is finished and tests are made. That a change takes place in steel after finishing, which materially affects the physical results, cannot be questioned.

"In connection with above, the following figures may be interesting. Test pieces were all cut from tires and duplicate tests, as far as possible, from the same part of the tire, as, owing to section of a tire and process of manufacture, tests from different parts of same section show a variation.

Elastic limit.	Ultimate strength.	Elongation.	Reduction.	Remarks.
		Per cent.	*Per cent.*	
53,490	107,460	15.00	19.20	Pulled within three days after tire was made.
56,037	108,700	16.30	24.30	Ten days later.
50,940	99,590	14.00	22.20	Pulled within three days after tire was made.
53,000	103,464	18.00	27.40	Ten days later.
56,037	111,050	10.00	12.37	Pulled within three days after tire was made.
61,130	111,410	15.00	21.50	Ten days later.
70,370	121,250	11.00	14.01	Pulled five days after tire was made.
71,980	121,970	14.00	17.89	Seven days later.
65,080	121,470	11.50	13.55	Pulled seven days after tire was made.
64,400	121,160	13.00	16.30	Fourteen days later.

"The tests were all pulled at the same speed. The dimensions of the first six test pieces were 2 × 0.5 inch and of the last four 2 × 0.798 inch."—"Engineering News."

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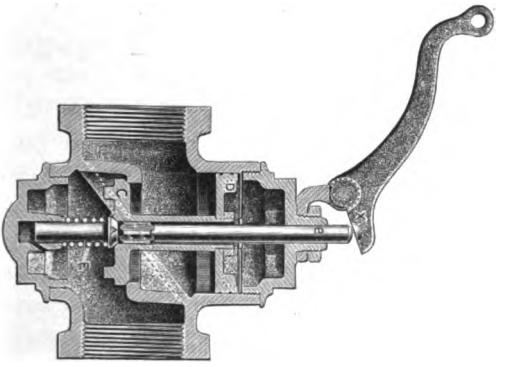
AUTOMATIC BALANCED WHISTLE VALVE.

The whistle valve here shown in section is intended to overcome the disadvantages inherent in the old designs. Under high steam pressures it is difficult to operate the ordinary whistle valves and keep them tight. In them the disk is not balanced, and as they close with the steam pressure the continual pounding on the seat soon causes them to become leaky. The valve here illustrated—made by the Lunkenheimer Company, of Cincinnati—can be operated under the highest steam pressures and can be kept tight without difficulty. The disk is balanced at all times, and when the valve is closing it does not hammer on the seat, but closes firmly and without shock or jar. In opening the steam pressure acts upon the valve disk in such a manner that the disk is raised from its seat almost automatically.



AUTOMATIC BALANCED WHISTLE VALVE.

The steam pressure on top of the disk normally holds it to its seat. A light pull on the lever is sufficient to open the small auxiliary valve. This admits steam through the opening in the center of the stem of the valve to the expansion chamber, where it acts upon the piston the area of which being larger than that of the valve forces it from its seat and allows the steam to pass through the valve. As long as the auxiliary valve is held open the main valve will be kept off its seat and the valve will be open. When the pull on the lever is released the pressure of the steam closes the auxiliary valve,

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and the main valve closes easily and without shock, as the steam which is entrapped in the expansion chamber tends to cushion and retard its movement. There is very little wear on the two valve seats, and they can be easily reground by taking off cap at end. These valves are made of gun-metal composition in all sizes from 1 to 3 inches inclusive.—"Iron Age."

TRAIN RESISTANCE.

In view of the limitations which our loading gages fix on the dimensions of our locomotives, the question of resistance of heavy trains at high speeds is a matter of considerable importance. Hitherto it has generally been assumed that the horse power exerted at the tender draw bar varied directly as the weight of the train. Thus consider Clarke's formula, according to which the resistance in pounds per ton $= \frac{S^2}{171} + 8$, where S is the speed in miles per hour. The horse power exerted at the draw bar to haul a 100-ton train at 40 miles per hour on the level would, according to this, be 180, and if the train was doubled in length and weight the power would also be doubled. This latter conclusion would seem, however, to be badly based, and in an article appearing in the current issue of the "Street Railway Journal" the results are given of some 150 experiments made by Mr. John Lundie, on the South Side Elevated Railroad of Chicago, in which the resistance was determined of a number of trains varying in weight from 20 to 100 tons. These figures show a most decided reduction in the coefficient of resistance as the weight is increased. Mr. Lundie's results are well represented by the formula:

$$R = 4\,S\left(0.2 + \frac{14}{35 + T}\right)$$

where R = the resistance in pounds per short ton (2,000 pounds), S the speed in miles per hour, and T the weight hauled in tons of 2,000 pounds. The experiments in question were made by the method adopted by several previous experimenters in which the train is started at a high speed, the power shut off, and observa-

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tions taken of the reduction of velocity, after different distances have been traversed. This plan, it will be remembered, was also followed by the committee appointed by the French Government to investigate the increased resistance due to curves.

That the resistance should diminish with the length of the train appears quite rational from the fact that this is partially dependent upon surface friction between the train and the air. In the case of water, Froude found that a varnished board, 2 feet long, showed at a certain speed a resistance of .41 pound per square foot, whilst with a similar board 50 feet long the resistance was but 0.25 pound per square foot. Head resistances being roughly proportional to the cross-section exposed are also proportionately less, the greater the length of the train. Hence generally all air resistances, which at high speeds form an important factor, may be expected to be less per ton hauled the longer the train. The journal and rolling resistances, on the other hand, will vary very nearly directly as the number of axles, and hence, approximately as the tonnage hauled. At low speeds the journal friction is very considerable, but rapidly decreases as the speed of the rubbing surface is increased up 100 feet per minute, being at this latter speed but one-third or so of its value when the speed is 6 feet per minute.

The total resistance of a train is thus made up of: (1) the internal resistances of the locomotive, which from experiments on horizontal engines will probably be 15 to 20 per cent. of the total power to develop; (2) the head resistance, which will be constant in total amount for all lengths of train, and will vary only with the speed; (3) the frictional resistance of the air, which will also increase with the speed, but be proportionately less the longer the train; (4) the journal and rolling friction, which is directly proportional to the number of axles, and diminishes as the speed increases up to a speed of about 14 to 20 miles per hour, and afterwards slowly increases.

Whether it is possible to include in a simple formula the effect of all these variables is perhaps doubtful, and that proposed by Mr. Lundie seems imperfect in form. It does not, however, agree at all badly with Mr. A. Sinclair's experiments on the New York

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Central line, and with those of Mr. P. H. Dudley on the same line and on the Philadelphia and Reading Railroad. The figures obtained by these experimenters were as follow:

Observer.	Line.	Speed. Miles per hour.	Weight of train. Tons.	Observed resistance. Pounds per short ton.	Lundie formula. Pounds per short ton.
A. Sinclar	New York Central.....	70	270	19.03	21.1
A. Sinclar	New York Central.....	69.6	270	19.8	21.2
P. H. Dudley....	New York Central.....	51.43	313	16.9	16.35
P. H. Dudley....	Philadelphia and Reading..	60	242.5	18.35	19.0
P. H. Dudley....	Philadelphia and Reading..	63.5	242.5	19.8	19.9
P. H. Dudley....	Philadelphia and Reading..	63.2	213	19.0	20.2

The agreement is, perhaps, as close as can be reasonably expected in a formula of this nature, but on applying it to the results obtained in some recent experiments with very heavy freight trains it appears that the observed resistance was much less than that given by the formula. Thus with a train weighing 940 tons running on the Chicago, Burlington and Quincy Railroad, the resistance on straight, level track was observed to be 5.5 pounds per short ton hauled in place of 8.3 pounds as given by the formula. Again, in a New York Central test, a train weighing 3,428 tons showed a resistance of about 4 pounds per ton when run at a speed of 20 miles an hour. The formula gives about five pounds.—"Engineering."

THE EXTINCTION OF WROUGHT IRON.

With the resistless force of a glacier, but with a rapidity which is only slightly appreciated, steel is now supplanting all forms of wrought iron. Forcible arguments in favor of iron for certain purposes may be made, numerous engineers may continue to specify iron for special classes of work to which they consider it is better fitted than steel, and prejudice may incline the masses of iron workers to prefer the material which can be welded with least

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trouble, but the day is near at hand when wrought iron will be an exceedingly scarce commodity. Arguments, preferences and prejudices are equally powerless to stop the advance of the metal which can so much more easily be produced in large quantities than wrought iron. Complaints continue to be heard among mechanics of hard spots in steel which make it of an uncertain character in working, as for instance in threading pipe; of its occasional unsatisfactory behavior in holding a coat of other metal, as in the case of galvanized steel sheets, and of its comparatively rapid oxidation when exposed to the weather or to the action of water. For such reasons a reaction of more or less strength is from time to time noted in favor of wrought iron, but the greater cost of puddled iron as compared with steel silences the complaints, the steel maker sedulously endeavors to turn out a more reliable product and steel continues to preserve its ascendency.

The end of this century, which is now near at hand, will in the estimation of even those who are deeply interested in wrought iron, see the end of wrought iron as a distinctive designation, except, perhaps, in the case of Swedish iron or some other high priced iron specialty. Ordinary bar iron will have completely disappeared from the trade. It is becoming increasingly difficult to secure material from which to manufacture genuine bar iron. Scrap has long been the chief dependence of the bar-iron manufacturer, who is prohibited by its cost from using puddled iron except for those who insist upon having muck bar iron without regard to price. But the great stocks of scrap iron are nearing exhaustion, iron rails are becomng a scarce commodity, and a new supply of cheap material for iron-rolling mills is out of the question. It is almost an impossibility now for an expert scrap dealer to detect the difference between wrought iron and soft steel in the old material offered him, and a guarantee that any lot of wrought scrap contains no steel is out of the question. Busheled scrap for common bar iron may almost safely be said to contain steel to some extent. And so much more steel is now being consumed than wrought iron that the production of steel scrap is increasing at a rate so rapid that wrought scrap will very shortly be principally steel.—"Iron Age."

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AN INTERNATIONAL STANDARD FOR METRIC SCREW THREADS.

The question of an international standard of metric screw threads was discussed at a Congress which met for the purpose at Zurich last October, and as a result of their labors a certain standard form of thread and a number of standard diameters for bolts were decided on. The form of thread adopted is based on the Sellars thread, which, it will be remembered, has the shape of an equilateral triangle truncated one-eighth its height at top and bottom. To insure interchangeability, and to reduce the wear on taps and dies, the Congress recommended that the bottom of the thread should be rounded off by any suitable curve, which should not deepen the cut more than an amount equal to one-sixteenth the pitch beyond the standard Sellars type. The apices of the threads, on the contrary, are to be left flat as in the Sellars system. The following standard sizes and pitches were decided on:

Diameter.	Pitch.	Diameter.	Pitch.
Millimeters.	*Millimeters.*	*Millimeters.*	*Millimeters.*
6 and 7	1.0	24 and 27	3.0
8 and 9	1.25	30 and 33	3.5
10 and 11	1.5	36 and 39	4.0
12	1.75	42 and 45	4.5
14 and 16	2.0	48 and 52	5.0
		56 and 60	5.5
18, 20, and 22	2.5	64 and 68	6.0
		72 and 76	6.5

The pitches chosen are, on the whole, somewhat finer than the Whitworth standards, though in the case of the sizes most used —say between $\frac{3}{4}$ inch and $1\frac{1}{2}$ inches—the two systems correspond very closely. This was to be expected, as the standards adopted by Whitworth and Sellars were due to a careful study of the results of many years' experiences. The principal factor in fixing them was the necessity of using threads which could be satisfactorily produced in cast iron. Where wrought iron or steel alone are employed, much finer threads can be substituted with advantage; and thus we find in bicycle work $\frac{1}{4}$-inch bolts with 30 to 26 threads per inch, $\frac{3}{8}$-inch bolts with 26 threads,

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and $\frac{9}{16}$-inch bolts with 20 threads per inch, sizes which to a certain extent, are becoming standard in the industry. It has long been a disputed point as to whether the Sellars or Whitworth thread is the better. From a mechanical point of view the sharp corners existing in the former are objectionable, but the form has certainly the advantage of being more easily originated with exactitude. This point had, no doubt, a considerable influence on the decisions of the Zurich Congress, as the threads there chosen will probably be independently produced in a dozen different establishments. Nevertheless the superiority of the Sellars system in this regard has, perhaps, been overestimated since, as a matter of fact, Whitworth bolts and nuts do interchange satisfactorily the world over. Indeed, a 1-inch Sellars' nut will, in practice, fit a Whitworth 1-inch bolt, the toleration allowed in ordinary work being sufficient for this. On the other hand, taps and dies in the Sellars' system wear more rapidly than the Whitworth, the sharp angles being points of weakness. The difference is, however, evidently not a serious one, or we should not have had American bolt and nut makers underselling us in colonial, and, indeed, in home markets, as they did last year.—"Engineering."

POST MORTEM REVELATIONS OF THE KEELY MOTOR.

We quote the "American Machinist" of January 26, 1899, in the following exposé of the "hidden mysteries" of the Keely motor:

We cannot but rejoice at the additional revelations which have been made of the "mysteries" of the Keely motor. These later revelations are the results of an investigation of the building occupied by Keely as a workshop, and in which the exhibitions of his apparatus were made from time to time. The undertaking was instituted by the "Philadelphia Press," and was conducted by a number of eminently competent persons, including the reporters of the newspaper, Prof. Carl Hering, consulting electrical engineer; Prof. Arthur W. Goodspeed, assistant professor of physics of the University of Pennsylvania; Prof. Lightner

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Witmer, professor of experimental psychology, of the same institution, and eminent as a student of and authority upon delusions; Dr. M. G. Miller, Coleman Sellers, Jr., and Mr. Clarence B. Moore, son of the late Mrs. Bloomfield Moore, so much of whose money had been absorbed in the Keely schemes.

The facts brought out by the investigations were, after all, only such as could have been easily discovered by less eminent and talented men, if they had been permitted to do so. The building was of a type quite common in Philadelphia. It was a two-story structure, built on a low foundation without cellar, and was 18 feet front and 45 feet deep; the upper story being, however, only 40 feet deep. There were three rooms on the ground floor and two rooms above, with stairway and hall, and an office partitioned off from the front room above. Every particle of the flooring and ceiling was torn out and the walls were closely examined. A lot of trap doors were found in the floors, varying in size from $1 \times 1\frac{1}{2}$ feet to 3×6 feet.

Five of these were in the front room on the ground floor, four in the middle room, and one in the back room, while on the second floor there was a $3\frac{1}{2}$-foot trap door in the center of the front room, a 4×4-foot trap in the center of the back room, and seven small traps distributed about other parts of this floor. Under the floor of the middle room on the ground floor there had been previously discovered a hollow spherical vessel, said to be of steel, weighing three tons and capable of sustaining an internal pressure of 25,000 pounds to the square inch. This vessel was near one of the trap doors and was buried in earth and shop refuse. To put it in the place where it was found, sections of two of the floor beams had been cut away and afterwards replaced. The vessel had a hole in the top tapped for pipe. Four feet away from this, and with an end just within the trap door, was a piece of heavy iron pipe, 14 feet long, with elbows on each end. Under the other trap doors nothing was found but heaps of ashes lately placed there. A false ceiling of wood had been put into one of the upper rooms, with a space of 2 inches between the boards and the timbers where pipes or wires might have been concealed, but none were found there. The floor of the back room up stairs

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was somewhat higher than that of the others, and on tearing this up, a piece of small tube, at first thought to be wire, was found running through holes bored in the floor beams. Mr. Sellers had previously found a similar piece of tube built into the partition wall almost opposite to where this was found. This had been put in after the wall was built, as the plaster was different from the orginal. The small tubes found are identical in size and appearance to others which appeared attached to the Keely machine, and which he asserted were merely wires for transmitting the vibratory movements.

This investigation we can scarcely avoid regarding as somewhat of the character of an autopsy. The facts discovered speak for themselves in a way which makes it quite unnecessary for us to offer a word of comment. These things are found after those who are still financially interested in the motor have taken away every portion of the apparatus that was ever visible to the public and much that was never exposed. If an investigation of the entire plant could have been permitted, it seems certain that functional relations could have been traced between the heretofore visible portions and those now for the first time revealed. Why should these things have been concealed? If there are those who can conceive that the concealment was consistent with any honest purpose, we are not to be counted with them, and there never has been a day when we could have been counted with them. While for so long a time the Keely motor, and the performances connected with it, were so prominently and so persistently kept before the public, it came in our way from time to time to speak of the matter, but we have never said anything calculated to foster any hope that there could ever come out of it anything commensurate with the claims advanced, or in fact anything of value to the world. Mr. Keely's ways were not the ways of an honest and truthful man, nor the ways of an inventor or discoverer of anything great, and that he was so long successful in his career is one of the marvels of the age, and all his apparatus is well deserving of a place in some museum where it may stand as a warning to the over credulous, whom, like the poor, we have always with us.

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THE KNAPP ROLLER BOAT.

The roller boats do not seem to be having an easy time of it. M. Bazin's, which was to do such great things, was a failure, and Mr. Knapp's, at Toronto, made only six miles an hour. The American inventor, however, tells us that this is the fault of the engines, and he is building a bigger vessel, which will be differently propelled. Experts look on askance, but Mr. Knapp is undismayed, and contributes a description and defense of his boat to "The Marine Review," Cleveland, Ohio, January 12. He says:

"I am satisfied that sufficient power can be applied to get practically unlimited speed, with a light draught, in this type of vessel, with little cost.

"I utilize the forces of nature, which aid me to get speed, while the present type is fighting nature. Consequently I will not need anything like the same amount of power, with vastly greater results. The Frenchman, Bazin, lately deceased, who has been called an eminent engineeer, could not succeed in getting high speed because of another principle involved, which he appears to have ignored, if he was aware of it, viz: the resistance of the water to the forward motion of the plow. His disks being thick at the center and thin at the circumference, always largely submerged, were in effect plows. He only talked of reducing skin friction, and so he would by that mode, but skin friction cuts very little figure at high rates of speed, even at 20 knots.

"The *Campania* takes 30,000 horse power to get 20 knots, while the *St. Louis* takes 20,000 horse power to get 19 knots. It is not skin friction but the resistance to displacement of the water at the bows they must overcome, this resistance increasing as the cube of the velocity at this speed and in an unknown quantity beyond that rate. This type is built with fine lines to get the least possible resistance, but the *Turbinia*, with her 50 horse power per ton of displacement, raised her bow out of the water, and her fine lines were in the air; she could not keep her bow in the water with this great resistance, and therefore she might just as well have been built with a square bow. The *Campania* takes 2½ horse power per ton of displacement, while

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my vessel will take about one-ninth of a horse power per ton of displacement, as proved by my experiments at Toronto.

"My theory is that rolling broadside on over the water, I very quickly obtain a resistance which tends to lift my vessel to the surface. As water is incomprehensible [incompressible?] and cannot be displaced quickly, I roll over it instead of through it, and it becomes a granolithic pavement, so to speak, under my vessel, because a body can only displace its own weight in water, and as soon as the resistance exceeds the weight of my vessel, it must practically be rolling on top. Then, like the railroad train running up a grade, it takes less power on the level, and so I get great speed with less power. This is at a light draught of say 12 feet in a diameter of 200 feet.

"I am told, however, by some engineers, who either can not comprehend the principles involved or have not given the subject sufficient consideration, that such a vessel, exposing so great a surface, can never be propelled against a gale of wind, and they instance the *Campania*, drawing 33 feet of water, or say two-thirds of her in the water, while nearly all of my boat is out of the water and exposed to the wind. Now it is not the wind that affects the *Campania*, but the water which strikes her with all its momentum, weighing 64 pounds to the cubic foot, the wave motion having a speed of say 70 feet per second; on the other hand, the wind is striking the one-third of her which is out of the water with a pressure of a few pounds to the square foot.

"Water is 825 times heavier than the air, but the *Campania* goes through it, necessarily at a reduced speed. With my vessel, the resistance of skin friction and the blow of a wave which is much below the center, knocking her legs from under her so to speak, are aids to speed. I turn the enemy into a friend, and am working with nature instead of fighting her. The wind can no more stop my vessel, weighing 17,000 tons and upward, according to her load, than it can a railroad train.

"I may say that I have many broad scientific men and several eminent engineers and naval architects who fully agree with me."

Mr. Knapp proposed to the Government to build a troop ship

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for 30,000 men on this principle. Some of the features of this vessel, which would be 800 feet long and 200 feet in diameter, were to be eight decks of varying sizes, each 8 feet 3 inches from floor to ceiling; seven hundred and eighty compartments 62.8 feet long, between the intermediate and outside skins, and 600 more between the intermediate and internal skins; an engine compartment in the middle of the ship, 200 by 168 feet, swung on journals at each end, and cabins swinging in like manner but independently. In the very bottom was to be a tank sufficient to carry enough fresh water to feed the boilers. The coal-bunkers were to have a capacity of 3,000 tons. Uncle Sam has not yet accepted this offer, and indeed he could scarcely be expected to do so. After all, performance is the conclusive test of every promise, and when Mr. Knapp's boat has raced with the *Campania* and beaten her, he may then build vessels by the dozen and ask his own prices.—"Literary Digest."

It appears that the dirigible qualities of this type of steamers in a gale have been relegated to the imagination.—(ED. JOURNAL.)

THE BURSTING OF SMALL CAST-IRON FLY WHEELS.

Mr. C. H. Benjamin has made a series of tests on small cast-iron fly wheels, using models (some 17 in all) of 15 and 24 inches diameter, the models conforming to actual fly wheels made by reputable firms and in practical use.

Wheels 1 to 10 had solid rims, with the exception of No. 5. Wheel No. 11 was a special wheel, but Nos. 12 to 17 had each two joints in the rim, and were 24 inches in diameter. The plan was to test these wheels to destruction, and the speed was obtained from a Don steam turbine with a speed up to 10,000 revolutions per minute. Mr. Benjamin in detailing the experiments drew from them the following conclusions:

1. Fly wheels with solid rims, of the proportions usual among engine builders and having the usual number of arms, have a sufficient factor of safety at a rim speed of 100 feet per second if the iron is of good quality and there are no serious cooling strains.

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In such wheels the bending due to centrifugal force is slight, and may safely be disregarded.

2. Rim joints midway between the arms are a serious defect, and reduce the factor of safety very materially. Such joints are as serious mistakes in design as would be a joint in the middle of a girder under a heavy load.

3. Joints made in the ordinary manner, with internal flanges and bolts, are probably the worst that could be devised for this purpose. Under the most favorable circumstances they have only about one-fourth the strength of the solid rim and are particularly weak against bending. In several joints of this character, on large fly wheels, calculation has shown a strength less than one-fifth that of the rim.

It is gratifying to notice the fact that since the subject of joints in fly-wheel rims has been so thoroughly ventilated, several of our prominent engine builders have changed the designs of their wheels by bringing the rim joints opposite the ends of the arms. The experiments, although at times a trifle too exciting, were interesting from first to last. The writer hopes to supplement them by others on models of the more recent rim joints.

The starting point of his design is a hollow rim, which he provides partly to get a greater depth of the rim to provide for greater strength of the sections considered as beams, and partly to get thin sections of metal instead of thick masses, of which the center adds its full quota of weight, but very little strength. The arms he also preferred to make hollow, though he had made some of I-beam section. Each arm was cast with its section and the joints were half way between the arms. The joints were made of shrunk links of the I-pattern, with the special provision that the links varied in length, so that at any one section, the section of the rim should be weakened by the recess for one link head only. Even this weakening, he pointed out, can be largely if not entirely prevented by making the core smaller at the ends where the links are located. In other words, while a solid rim must be weakened at the joint by the metal cut out for the links, a hollow rim may be reinforced at this point by additional metal on the inside, so that the joint shall be substantially as strong as the solid part of

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the rim. Another point about which he was very particular was to have his wheels run true—"a wobbling wheel is a dangerous wheel."—"Engineering."

ACCIDENT TO THE MACHINERY OF THE *CINCINNATI.*

On November 18, 1898, while getting under way at Guantanomo, Cuba, the *Cincinnati* met with a serious accident resulting in a fracture across both frames of the port after low-pressure cylinder.

Without dwelling upon the cause of this accident, which as yet has not been sufficiently and fully explained, the rupture having taken place while turning the engines preparatory to reporting ready to get under way, the manner in which repairs were made and by which the ship was enabled to proceed North under her own steam at a fairly good speed was as follows, and is graphically shown in the accompanying illustration:

The inboard guide as well as both after inboard and outboard columns were found to be cracked, and it was necessary to throw out of use the after low-pressure cylinder.

In order to work safely the impared port engine with triple-expansion effect, the following work was done:

1. Taking down connecting rod, valves and valve gear of after low-pressure cylinder.

2. Fitting steel circular plates over the ends of both valve-chest linings so as to prevent the steam from the intermediate cylinder passing directly into the condenser. The upper and lower plates in each valve chest are held in place by seven (7) three-quarter ($\frac{3}{4}$) inch rods uniting them; the pressure from the intermediate cylinder thus assists in making a tight joint. False steel bonnets replaced the upper cast-iron valve-chest bonnets, as the ribs of the old bonnet interfered with the internal plates.

3. Dropping piston to bottom of stroke. Fitting heavy lignum vitæ shores on top of crosshead, and then fitting four (4) vertical beams between these shores and lower cylinder head.

4. The piston was then secured to the lower part of the engine frames by passing small three-eighths ($\frac{3}{8}$) chains over the

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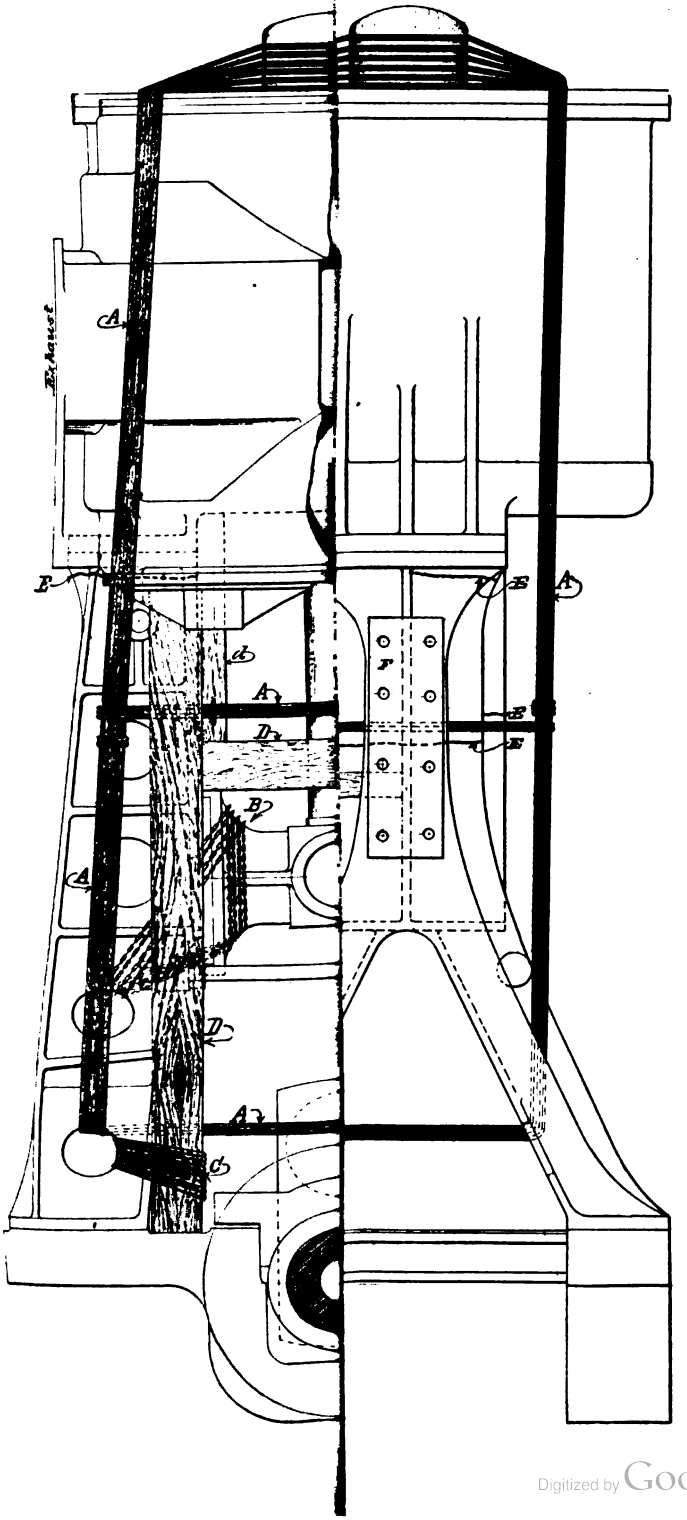

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upper ribs of the crosshead. The cylinder was thus tied in one way to the unimpaired parts of its sustaining columns.

5. The cylinder was best tied, however, to the frame in this manner:

Through the lowest lightening holes in both columns, and over the after low-pressure cylinder head and around its bonnet, was passed a wire hawser. This hawser was about one hundred and twenty (120) fathoms long and made of two and one-half ($2\frac{1}{2}$) inch rope. The several bights were made taut by chain purchases. The twenty-six (26) vertical parts were then swiftred together with the end of the wire. When completed the parts took up an equal strain, and there seemed absolutely no give to the structure.

6. A steel butt strap five-eighths ($\frac{5}{8}$) inch thick was bolted to the inboard frame, just over the middle and most extensive crack.

7. The overhanging valve chest was shored by two seven by seven (7×7) inch, hard-wood vertical beams, the lower ends resting on the bed plate. The shores were free of the cap. By fitting them into place there was a tendency to prevent any undue strain being thrown on the exhaust pipes. The bases of the shores were lashed to the lowest parts of the frame. The upper ends were recessed into the ribs of the valve-chest bonnets, the bonnets having been turned end for end. Chocks were then fitted between the shore and frame to increase the rigidity.

After the sea trial, a careful examination of the parts comprising the structure was made, and it was not found necessary to take up any slackness, nor to change any detail of the repair.

As the *Cincinnati* has four-cylinder triple-expansion engines, the throwing out of one of the low pressure cylinders still left, three cranks operatable and the running of the engine was, from all reports, excellent.

THE NERNST ELECTRIC LAMP.

The possibility of a most far-reaching revolution in the matter of electric lighting was foreshadowed in a paper read before the Society of Arts, on February 8th, 1899. In this paper Mr. James Swinburne gave an account of the remarkable lamp which

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has been devised by Professor Walther Nernst, of Gottingen. This lamp resembles the ordinary glow lamp in that the light is obtained by passing a current through a mass of material of high resistance, which is raised to incandescence by the heat thus generated. In place of a carbon filament, however, Professor Nernst makes use of a rod of magnesia, thoria, or some similar refractory oxide, but the exact nature of the body now used was not disclosed by the lecturer.

At ordinary temperatures such oxides are amongst the best-known non-conductors of electricity; but on heating, like most other non-conductors, their resistance is diminished to an astonishing degree. This property of non-conductors has, of course, been well known for a long time. Indeed, some twenty-three years back, a paper by Professors Ayrton and Perry was contributed to the Proceedings of the Royal Society, in which it was shown that glass, at a temperature of only 100 degrees centigrade, showed quite respectable conducting properties. Such observations, however, led to no practical results till Professor Nernst conceived the idea of constructing incandescent lamps in which the radiating body was one of these ordinarily non-conducting oxides, rendered conducting by highly heating it and then maintaining it at a high temperature by means of an electric current passed through it. The efficiency of such lamps is, it appears, very high, about 1.5 watts being needed per candle-power, whereas the ordinary carbon glow lamps ordinarily supplied take in general about 3.5 watts, so that the saving of current is very substantial. The light emitted is of excellent quality, having none of the greenness to which so many users of the Welsbach gas light so strongly object. The rod requires no protection from the air, in fact it will not, Mr. Swinburn states, work in a vacuum, owing, perhaps, to the fact that the rod is electrolyzed by the passage of the current, and a supply of oxygen is, therefore, needed at the positive terminal to reoxidize the reduced metal. In fact, the whole lamp consists of a rod of the oxide, apparently about $\frac{1}{16}$ inch in diameter by 1 inch long, supported between two platinum terminals.

To start the lamp a Bunsen burner or a spirit lamp is used,

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though with the smaller sizes a match will suffice. With one or other of these the rod is heated, and becoming thereby a conductor, the current is able to pass as soon as turned on, when it rapidly raises the whole mass to a very high temperature, at which it gives off a most brilliant light. With the oxides originally used the life of the rod was short, about 40 hours, but now this has been extended to over 500 hours. Mr. Swinburne further showed that a broken rod would, on the fractured surfaces being placed in contact, work practically as well as a whole one. The necessity of starting this simple form of lamp by an extraneous source of heat is, no doubt, in some respects a drawback, and accordingly self-starting lamps have been prepared in which a coil of platinum wire is placed adjacent to the rod. On switching on the lamp the current first passes through this coil, the heat generated being sufficient to raise the rod of oxide to the conducting point, and the lamp accordingly lights up, after which the platinum resistance is automatically cut out. This arrangement would seem to be somewhat expensive; but it has to be borne in mind that when these self-lighting lamps are used, the only part requiring replacement is the oxide rod, and the renewal of this is a simple matter. Since the resistance of the rods diminishes as the temperature increases, it is necessary to add a supplemental resistance to each, if the lamps are to be run in parallel. This resistance is about 10 per cent. of the total, and the energy wasted in it is included in the 1.5 watts per candle-power mentioned above.

One great difficulty in modern incandescent electric-lighting practice is the maintenance of a steady electromotive force at the lamp terminals. Very small variations in this factor make immense differences to the durability of the filament and to the light given. Mr. Swinburne holds out hopes that the Nernst lamp will be much less sensitive to such variations of potential difference, and should these anticipations prove justified, the new lamp will have most excellent prospects of commercial success. The lamps can, moreover, be easily made to run at high pressures, certainly at as much as 500 volts, and, perhaps, Mr. Swinburne states, at as much as 1,000 volts. The rods, which are the

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only portion of the lamp requiring renewal are, it is said, exceedingly cheap to make, though this, alas, does not necessarily imply that they will at the outset be supplied at correspondingly low prices. The efficiency of the lamp, it is stated, does not diminish as time goes on.

The discussion which followed the reading of Mr. Swinburne's paper turned mainly on the cause of the efficiency of the Welsbach burner. Mr. Swinburne, in his lecture, had attributed it entirely to the high temperature to which it is exposed, stating that platinum would readily melt when placed close to the mantel. Other speakers were, however, inclined to attribute the efficiency either to selective absorption, whereby radiations of large amplitude are absorbed by the mantle and the energy, afterwards emitted as radiations of shorter wave length, or else to a sort of catalytic action similar to that occurring with platinum sponge, which can be made to glow when a stream of hydrogen is directed on to it. Mr. Swinburne, however, holds strongly to the opinion that the efficiency is solely a matter of temperature. His theory is that most bodies placed in a Bunsen flame fail to take the temperature of the latter owing to their high emissivity. Thoria, on the other hand, has a very low emissivity, and consequently reaches a very high temperature. To increase its light-giving power, about $\frac{4}{10}$ per cent. of ceria is incorporated with the thoria. This ingredient has much greater emissivity than the thoria, and being in intimate contact with the latter, reaches about the same temperature. As time goes on, however, the ceria evaporates, so that an old mantle consists of practically pure thoria, and the light falls off accordingly.

The only other point of interest raised in the discussion was of possible anticipations of Professor Nernst's invention. No one contended that any effective claims to priority could be established, but Mr. Campbell Swinton recalled Jablachoff's kaolin lamp, in which light was obtained from a rod of kaolin maintained at incandescence by means of an electric current, whilst Mr. Swinburne himself recalled the Solieil lamp exhibited at the Inventions Exhibition in 1885, in which the light was partially obtained from incandescent lime.—"Engineering."

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MACHINE CONSTRUCTION IN AUSTRIA.

In Austria machine construction is making slow but steady progress. Fifty years ago the total output of the Austrian machine shops was valued at 2,000,000 florins; last year it was worth 30,000,000. One great obstacle in the way of the development of the machinery industry in Austria is the lack of specialization. As a general rule, the Austrian manufacturers do not confine themselves to one particular line; many kinds of different machinery are made under the same roof, whereas, as a general rule, the modern machine industry demands, as far as possible, special processes of manufacture in order that the cost of manufacture may be reduced and the possibilities for an extension of foreign trade may be increased. It must, however, be borne in mind that in Austria the general conditions of production, not only for home consumption but for export, are such that manufacture can, as a rule, be carried on only to a small extent relatively. Works turning out special machinery need a good home market and a lively export trade, and for both these conditions Austria is very unfavorably situated. High tariffs and high cost of iron are the main difficulties with which the manufacturer has to contend. To-day, just as it was fifty years ago, the Austrian machine industry aims mainly at supplying the home market and plays no part in international trade. During the last few years the total annual exports of machinery averaged from 3,000,000 to 5,000,000 florins in value, while the importations were of a yearly value of 19,000,000 or 22,000,000 florins.

The Austrian machine builders have at different times petitioned for Governmental interference, but it is very doubtful whether the Government is in a position to exercise any favorable influence upon the industry by any departure from its present attitude. The only thing which possibly, and even then only to a small extent, could affect advantageously this industry is the abolishment or partial reduction of duties, taxes and other fiscal burdens. Besides this favor the manufacturers also demand a revision of the laws dealing with accidents in industrial establishments, a revision of the treaties of commerce, and considerable reductions in the railway and water freight rates. An

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agitation for the abolition of the iron trusts is also being very vigorously conducted. But, in spite of all these unfavorable surroundings, the last fifty years has seen a wonderful progress in this industry. In 1848 there were in Vienna and lower Austria sixteen machine works employing some 2,400 hands; in Bohemia, ten works with 1,000 workmen. Besides these there were, perhaps, five works with some hundred men. Of these only five or six were of any importance, while the other ones were more in the nature of repair than machine shops. In Vienna there were two locomotive works—those of the American, Norris, and those of Specker, which afterward went into the hands of the Kaiser Ferdinand Railway Company.

To-day there are, without counting numerous small workshops, some one hundred and sixty machine shops in Austria, giving employment to about 25,000 hands, and in which a capital of at least 70,000,000 florins is invested. All the locomotive works are joint stock companies; the oldest is that of G. Sigl, in Neustadt, near Vienna (Wiener-Neustadt). These works represent a capital of 1,960,000 florins, and turned out in 1896 sixty-nine locomotives and forty-eight tenders, valued at 2,100,000 florins, besides steam engines, boilers, etc., valued at 690,000 florins. The Wiener Locomotivsfabrik Actiengesellschaft in Wien-Floridsdorf have about the same capacity and represent about 1,620,000 florins capital. Their output in 1896 was valued at 2,400,000 florins and comprise seventy-one locomotives and thirty-three tenders. In the same year the Government locomotive works turned out a value of 2,600,000 florins. The total output of all Austrian locomotive works comprised in 1896 two hundred and sixteen locomotives, and one hundred and twenty-eight tenders, besides other machinery and parts to the value of 1,120,000 florins. The workmen employed in all locomotive works numbered about 3,500. During many years the Austrian locomotive works built many engines for foreign countries, such as Russia, Roumania, Italy and Spain, and even France.

To-day the machine industry in Bohemia and Moravia is also of great importance. Of late years a number of large works have been established in these countries. They build steam engines,

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boilers, brewery, distillery, sugar and texile machinery. The large works of the Maschinenbau Actiengesellschaft, vormals Breitfeld Danek & Co., in Prague, filled orders to the value of 3,300,000 florins in 1896. Other very important works are the Prager Maschinenbau A. G., vormals Ruston & Co., and the works of F. Ringhoffer at Prague. The Erste Brünner Maschinenfabriks Gesellschaft executed orders (1896–97) to the value of 1,756,000 florins, turning out seventy-three steam engines, eighty-seven boilers, etc. Many other important works in Bohemia and Moravia were running on full time during the past year. A high rank among the Austrian machine works is occupied by the Stabilimento Tecnico Triestino at Trieste, founded in 1856, and working with a capital of 3,000,000 florins.

Machine tools are not made to such an extent as to meet the requirements of the market. The principal Austrian makers are F. Reitbauer, Ernest Dania & Co. and Hoerde & Co., all of Vienna.

There is no doubt that with proper efforts our exports to Austria could largely be increased. In 1897 the importation of machine tools amounted to a value of about 950,000 florins. Large quantities of machine tools are still imported from Germany and Great Britain, although there is scarcely a machine shop in Austria in which American tools, however few, cannot be found. By far the greater part of the machinery imports consist of textile machinery (4,800,000 florins in 1897, of which 2,100,000 cotton machinery), which is almost entirely of English origin. Sewing machines were imported to the value of 1,200,000 florins, or about $504,000, to which we contributed only $7,853. Agricultural machinery was imported to the value of about 1,000,000 florins ($420,000), and even in this item our share was very unimportant, our total exports of agricultural machinery to Austria amounting in 1897 to $13,699. Portable engines were imported to the value of 800,000 florins ($336,000), to which the United States contributed scarcely anything. The imports of electro-dynamic machinery, which came chiefly from Germany and Switzerland, were valued at 780,000 florins.

A considerable loss to the Austrian machine industry has arisen through the development of the Hungarian machine industry.

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And up till now it has been impossible for the Austrians to discover a new outlet which could compensate them for the loss of the Hungarian market. As a consequence, the works are more and more being established in the country instead of in the large towns, country labor being found much cheaper and the means of transportation adequate. Of late quite a number of old established works have been removed from the cities to the country. What the coming years will bring can scarcely be said. The fact remains, however, that Austria should be closely observed by Americans, with a view to seizing every opportunity which may present itself.—"Iron Age."

ADVANTAGES OF MECHANICAL DRAFT OVER CHIMNEYS FOR BOILER FURNACES.

Mr. Walter B. Snow, at the recent meeting of the Northwestern Electric Association, strongly advocated the substitution of mechanical draft in place of chimney draft for furnaces. This can be accomplished either (1) by forcing the air into a closed ash pit, and maintaining therein a pressure in excess of the atmosphere; or (2) by exhausting the air and gases from the flue or uptake, and thereby creating a partial vacuum which will cause a constant onward flow of air to the combustion chamber. The first method is designated as "forced draft" and the latter as "induced draft." In both types of mechanical draft centrifugal fans are used to render the draft conditions positive at all times.

The advantages of mechanical draft as stated by the author are its positiveness and flexibility. Its positive character renders its action independent of the weather; and its flexibility lends to it that characteristic so lacking in the chimney, the capability of exactly adapting the intensity of the draft as well as the volume of air to the requirements of the instant. Especially is this advantage noteworthy in cases where the service is irregular in character, that is, when the demand for steam is fluctuating, as, for example, in traction service where they are often sudden and immense.

Again, a convenient feature of mechanical draft, pointed out

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by the author, consists in the ability to burn cheap fuels, which are almost invariably of small size and require an intensity of draft which is not readily created by means of a chimney.

Also, the positiveness and intensity of the draft produced by a fan makes it a valuable aid in connection with the suppression of smoke—a question that is of the first importance in cities where soft coal is the only fuel used.

Turning to the economic side of the question, the author points out that the chimney is an absurdly inefficient means of creating an air movement, affirming that it can readily be shown that under the ordinary conditions of steam-boiler practice a fan will remove a given amount of air with the expenditure of only one seventy-fifth of the cost required by the chimney. Other economic advantages are itemized, but need not be specially referred to. The concluding portion of the paper contains a valuable statement of the comparative cost of the two systems, which should receive the careful attention of steam users. This is accordingly quoted:

"In order that a definite comparison may be made between the two methods of draft production, a certain 1,600-horse-power plant has been taken, of which the cost is known. This consists of eight modern water-tube boilers, two economizers, and a chimney 8 feet in diameter by 180 feet high. The latter is located just outside the boiler-house wall. If a duplex induced mechanical-draft apparatus, each fan capable of operating the entire plant, should be substituted for the chimney, it could be placed immediately above the economizers, and with its attached engines could be rigidly supported by beams resting on the economizer walls. A short stack would serve to discharge the gases above the roof.

"The cost of the chimney, with damper regulator and dampers, is $9,300; that of the fans, engines, draft regulation and short stack, installed complete, would be about $3,500, or only 38 per cent. of the draft-producing apparatus for which it is substituted. That is, the saving would be $5,800.

"With the increased draft produced by the fans it would be possible to raise the combustion rate and the steaming capacity, or, what is equivalent, the same capacity might be maintained

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with a less number of boilers. Suppose one of the eight boilers be omitted from the original design, making the plant 1,400 nominal horse power. A further saving of about $4,000 may thus be secured.

"If the land be valuable the reduction of space incident to the employment of mechanical draft may have an appreciable effect. If worth, say, $2 per square foot, the saving by omission of chimney and one boiler would be about $2,000. The total saving in first cost resulting from an expenditure of $3,500 for mechanical draft may thus be shown to be $11,800; that is, the saving is nearly three and one-half times the expenditure necessary to secure it. Obviously there is a coincident reduction in the fixed charges for interest and taxes.

"The power expenditure for operating the fans should not be practically appreciable in any well-designed plant in which provision is made to utilize the exhaust steam from the fan engine.

"The most direct saving in operating expense which may be secured by the introduction of mechanical draft is that resulting from the utilization of cheaper fuel. Such a plant as previously described would, under good conditions, probably require at least 8,000 tons of high-grade coal per year, operating ten hours per day. If a saving of only 25 cents per ton could be effected it would represent an aggregate of $2,000 per year, a very good return on an investment of $3,500. But in many cases much greater savings may be brought about. A case in point is that of the United States Cotton Company, Central Falls, R. I., where, with a 1,000-horse-power boiler plant, the fuel originally employed with chimney draft was George's Creek, Cumberland, costing (at that time) $4 per ton. With forced draft a mixture of No. 2 buckwheat screenings and Cumberland is now used, costing $2.62 per ton. The saving has been about $125 per week, enough to pay for the special steam fan in about six weeks.

"Other direct and indirect advantages of mechanical draft might be presented, but the limits of the paper will not permit. If it were not for its rough-and-ready character, the chimney would long ago have been discarded, because of its wastefulness. In the search for the highest efficiency such waste can no longer be

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ignored, and when dollars and cents are concerned, crude methods must give way to those of greater refinement. It is for this reason that the most progressive engineers of the present day are not only considering but adopting mechanical draft as a substitute for the chimney."—Franklin Institute.

MISCELLANEOUS.

MANUFACTURE OF STEEL CASTINGS IN THE UNITED STATES.—Mr. Stewart Johnston read an instructive paper on this subject at the recent meeting of the American Foundrymen's Association. After giving a historical sketch of the growth and development of this branch of the metallurgic arts in the United States, and some useful hints respecting the difficulties encountered in practice and how to overcome them, he gives the following statement of the present state of the art:

"The uses to which steel castings are put are beyond enumeration, and are daily becoming more varied, although at the time of their introduction in the United States, in the seventies, their position in the commercial world was one of insignificance. Limited to a few lines, the production in first years did not annually exceed 200 tons. Steel castings now invade every field in metallurgy save the one occupied by the chilled-iron roll when used for rolling finished steel, and for that purpose no steel cast substitute has ever been considered a dangerous rival. It is estimated that the annual production of steel castings in the United States is from 80,000 to 100,000 tons."

WATER FOR BOILER USE.—The "Broad Arrow" of December 31st notes that the Admiralty have forbidden the use of shore water in boilers of torpedo boats, claiming that air and foreign deposits were carried in this water to the great detriment of the boilers and the clogging of the tubes. Distilled water from their own evaporators is to be used exclusively.

This matter of using shore water has always been avoided as far as possible in our Navy, but probably through the fact that fire-tube boilers we have found the deposits resulting from this

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use to be so slight compared with the occasional salting which occurs by the sometimes unavoidable use of sea water, that the attention of our own officers to the possibilities of ruining small water tubes by using shore water has not been made sufficiently important.

There can be no question as to the importance of restricting the quality of water used in torpedo-boat boilers to that produced by evaporators, and our own Government has taken the matter up of increasing the evaporating plant on these boats as well as of our ships, in order to so limit it.

THE FUTURE OF ACETYLENE AS AN ILLUMINATING AGENT.—In a thoughtful editorial on this subject, the "Electrical World" advances the following views upon the role which acetylene may be expected to play as an illuminant in competition with gas and electricity:

"As a competitor in the illuminating field acetylene will probably be a greater rival of illuminating gas than of electric current, and it is possible that its success will be of more benefit than harm to the latter. It is the old story over again of one rival stimulating another in competition, and by means of improved service and reduced cost increasing the demand by an amount greater than its own supply. Illuminating gas, electric lighting and acetylene all have their own individual advantages which, to a certain extent, outline certain fields of application of each in which the others cannot compete. For vehicle lighting, including train lighting, and for gas distribution where but a small percentage is used for fuel, acetylene will probably show advantages over other forms of gas; while for combined heating and lighting service from one system, illuminating gas cannot be met by either acetylene or electric current, but for isolated plant service, theater lighting and all cases where ease of control from a distance or convenience of ignition or adaptability to special decorative effects are of any importance, the electric current has the advantage. It cannot be met by its competitors in the qualities of safety, neatness, cleanliness, convenience and elegance."—Franklin Institute.

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NEW METHOD OF WATERPROOFING PAPER.—The German journal "Neueste Erfindungen," describes the following method of making a water-proof paper: The sheet is coated on both sides with a solution consisting of one part gelatine, four parts water and one part glycerine. When dry, the paper is immersed in a 10 per cent. solution of formalin. After this treatment, the paper is said to become impervious even to steam.

IRON-NICKEL ALLOY FOR INCANDESCENT ELECTRIC LAMPS.—The so-called leading-in wires for attaching the carbon filament and making electric connections have thus far been made of platinum. This appears to be the only metal which has the same rate of expansion and contraction as glass, and its use for this purpose has consequently been compulsory with the manufacturers of electric incandescent lamps, since by no other means has it been found possible to avoid leakage of air into the interior of the bulb and the speedy destruction of the filament.

From experiments lately conducted at one of the Reichanstalten in Germany, on nickel-iron alloys, it has been developed that the coefficient of expansion of such alloys varies according to the percentages of the two metals present. Furthermore, it is said to have been experimentally demonstrated that an alloy of iron and nickel containing 45 per cent. of nickel possesses the same rate of expansion as platinum, and it is proposed to use this alloy to replace platinum in the manufacture of incandescent electric lamps.—Franklin Institute.

ARMOR TESTS.—At Ridsdale, the proving ground of Messrs. Sir W. G. Armstrong, Whitworth & Co., Limited, a trial took place recently of a plate representing the armor of the Japanese battleship *Asahi* now building on the Clyde by the Clydebank Enginering and Shipbuilding Company, Limited. The makers of the armor are Messrs. John Brown & Co., Limited, of Sheffield, and the trial plate, 8 feet by 8 feet 8.8 inches thick, was cut from a partially finished belt plate selected by the Japanese authorities from among those in course of manufacture. The attack consisted of three blows from 8-inch armor-piercing shot

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of 250 pounds weight, made for the Japanese Government by Messrs. Armstrong, on the Wheeler-Stirling process. The striking velocities of the three rounds were respectively 1,859, 1,964 and 2,039 foot-seconds, and all the shots were smashed to pieces without indenting the plate beyond an estimated depth of 3 inches. Except for a few very fine hair-cracks in the face, and the usual splintering of the surface round the point of impact, no other damage was apparent. On later examination the back was found intact except for three slight bulges, of which the most prominent did not exceed 1½ inches in height.

ANOTHER NEW ELEMENT.—The discovery of a new element, which has been named polonium, is announced in a recent communication by M. and Madame Curie to the Paris Académie des Sciences. The reasoning which led the discoverers to suspect the existence of this new body is of interest. Some time back M. H. Becquerel drew attention to the fact that the salts of uranium had the property of emitting a radiation having properties very similar to the X-rays. Thus they would impress a photographic plate, traverse materials opaque to ordinary light, and, further, make the air through which they passed a conductor of electricity. Further researches showed that uranium was not alone in emitting these radiations, as thorium and its compounds enjoy a similar property. Madame Curie further noted that certain specimens of pitch-blende showed the property even more powerfully than uranium itself, and was thus led to suspect the presence of a new element. By an elaborate chemical investigation, M. and Madame Curie have now succeeded in isolating this body in the form of a sulphide. From a chemical point of view, the new element resembles bismuth, but its radiating powers are said to be 400 times those of uranium.—"Engineering."

THE QUESTION of the porosity of thin steel plates under heavy hydraulic pressure having been raised, experiments have been carried out at the Washington Navy Yard with the view of settling the point in a practical way. Pieces of sheet steel of ¼ inch, ⅛ inch, $\frac{1}{16}$ inch and $\frac{1}{32}$ inch in thickness were subjected to a

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water pressure of 6,000 pounds per square inch, and in no case was any percolation found. A $\frac{3}{8}$-inch rivet joining two $\frac{1}{8}$-inch plates also proved tight under the same pressure. A test was also made to determine the friction of water under high pressure, and, while it was inconclusive, there was no evidence that the friction of water under high pressure was any greater than the friction of water not under pressure.—"Engineering."

ELECTRICAL VEHICLES IN THE RECENT STORM.—The severe snowstorm in New York city on November 26th last, gave the first opportunity for observing the behavior under trying climatic conditions of the cabs and broughams operated by the Electric Vehicle Company. To the surprise of even some of their most staunch upholders, the electric automobiles gave better service than did horse-drawn vehicles. The cabs ran through the whole night, the last coming in about 6 o'clock in the morning, by which time the snow had reached an average depth of about 8 inches, and much more where drifted. Other cab companies turned over orders to the electric service rather than fill them themselves. No very marked change in their running was noticed, although the mileage per charge of battery was, as a precautionary measure, greatly reduced, the vehicles being ordered in for fresh charges after covering ten or twelve miles. The ease with which they ran is probably due to the large pneumatic tires, 5 inches in diameter, with which they are fitted, which give a large bearing surface and reduce the tendency to cut deeply into the snow.

THE WEAKEST LINK IN THE CHAIN.—The electric motor directly coupled or geared to its load, with no intermediate mechanism which can slip, as can a belt, becomes, especially with high-gear ratios, a source of great possible strains. Unlike the steam engine and other sources of mechanical power, its maximum torque is, as a rule, a great many times that of its normal load, and, especially in the case of shunt-wound motors, any obstruction to the movement of the load tending to reduce the speed causes an instantaneous application of the great force available.

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Especially is this the case with motors driving such loads as cranes, elevators, etc., where the speed reduction is considerable and worm gears are commonly used. A recent disaster that was probably in part due to this very cause is the fatal accident which occurred recently in an electrically-driven elevator in New York city. Here it appears that the car came down with full speed against the bumpers and the motor continued working, lifting the counterweights after the car had struck, in spite of the greatly increased load, until the counterweights struck at the top of the shaft, throwing some of them out of the frames, whence they fell and smashed through the car with fatal results. In other instances motors have torn the cables loose from elevator drums, cars, or counterweights, broken the wheel spiders or stripped the gears.

In cases of this kind the weakest point of the system will, of course, yield first to the strain, and, very fortunately, the weakest point can be readily made a part of the electrical circuit, the breakage of which causes no damage whatever. The action of fuses is too slow for such sudden loads as are liable to be imposed on rigidly-coupled machinery, so that circuit breakers should always be installed. Unfortunately the circuit breaker, like the safety valve of early boiler installations, is very readily overweighted or tied in, and one that, like most modern types of safety valves, could not be tampered with would be a blessing for such service. With a breaker that could be absolutely depended upon the maximum strain, outside of the inertia effect of fly wheels, etc., could be exactly calculated and allowed for. In most of such loads, among them cranes, elevators, etc., there is no great amount of stored kinetic energy, and where this is necessary, as in printing-press service, etc., other safeguards might be provided if necessary.—"Electrical World."

THE X-RAYS IN METALLOGRAPHY.—The latest application of the X-rays is to the study of metallic alloys. When the alloy is composed of two metals having different transparencies to the rays, radiographs taken of thin plates show the separation of the two during solidification. As an example, it is stated that

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an alloy of aluminum and gold shows on solidification the segregation of a definite compound of the two metals, which separates in well-defined crystals.

THE STEAMSHIP *St. Paul*, of the American Line, which had been overdue since January 7, arrived in New York on January 10, after a trip of 9 days, 20 hours and 16 minutes, the slowest run ever made by her. The delay was due to a crack in an elbow of the 16-inch main steam pipe leading to the starboard engine, which made it necessary to reduce the steam pressure to 100 pounds. As soon as the crack was discovered, without shutting down the engines, two heavy clamps were placed about the pipe and screwed up until the opening was practically closed. The injured section was then wound with ½-inch copper wire. The whole operation requiring about one and one-quarter hours. The accident was discovered when about 800 miles from The Needles, and the remainder of the voyage was made at a speed of about 13 knots, although this was reduced at times by the heavy head seas.—"Engineering News."

THE TAPER OF PIPE THREADS.—The pipe tap should have a greater taper than the threading die. Just how much greater may be a matter of choice, but one inch taper to the foot for the tap and three-quarters for the die is good enough in practice and avoids all necessity for stuffing boxes, red paint or other dope. The reason is easy to see. If the pipe has the less taper the joint makes up at the end of the pipe first, as it should do, and that point being tight all the rest must be tight too. With moderate screwing up the pipe end becomes smaller and is ready to expand with the pressure, while the fitting becoming larger is already under tension to prevent further expansion. With a difference of one-quarter of an inch in the tapers a hydraulic pipe will readily fit the whole distance the thread is screwed in. The joints so made are good for pressures up to 10,000 pounds and can be taken apart and put together indefinitely. Oil that is good enough for the die is good enough for the joint, and no dope is of any value.—Correspondent in "American Machinist."

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SHIPS.

UNITED STATES.

Missouri.—Decision has been reached regarding the boiler plant of this vessel, which is that the arrangement will include twelve Thornycroft boilers placed in four separate water-tight compartments, each compartment being 48 feet long and 20 feet 6 inches wide. Thus three boilers will be in each compartment, two back to back, near the middle of the compartment, and one with its back to the center athwartship bulkhead. This gives an end single fire room 8 feet 6 inches long, and a middle double fire room 12 feet long in each compartment. The boilers are to have a total tube-heating surface of about 60,000 square feet, and a total grate surface of about 1,000 square feet. Details of the hull arrangements will be very similar to the *Maine's*, but this, together with the details of the *Ohio's* hull, will be published as soon as finally settled.

Ohio.—The arrangement for the *Ohio's* boilers will probably be similar to that of the *Missouri*, although at this writing the question has not been absolutely settled.

Wisconsin.—This first-class battleship was launched at San Francisco on Saturday, the 26th of January, 1899. She will carry four 13-inch guns and fourteen 6-inch quick-firing guns. She has a displacement of 12,325 tons, and a speed of 16½ knots. Her coal capacity is 1,500 tons. Description of this vessel was given on page 797, volume viii, of the JOURNAL.

Farragut.—On December 2, 1898, after verifying weights and distribution of same, and getting draughts as follows: forward, 4 feet 9⅛ inches; aft, 8 feet 2¼ inches; mean, 6 feet 5 11/16 inches; displacement, 236.3, a successful one-hour run of the *Farragut* for her final speed trials was made over a measured mile in San Francisco waters. The first part of the run began at 10·28·55 A. M., and ended at 10·56·55 A. M., or 28 minutes, and the second part of the run began at 11·02·00 A. M., and ended at 11·34·00 A. M., or 32 minutes, making a trial of 60 minutes, or one hour's

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run as required. The interval of time consumed in turning between the first and second parts of the run as recorded by the Board was 5 minutes and .05 seconds.

During the runs the recording of the counters were taken with the following results:

No.	Interval.	Starboard.		Port.		
1	7½ minutes,	442.53		425.33		
1	7½ minutes,	442.53	A	425.33	B	419.3
2	7½ minutes,	436.26		423.20		
3	7½ minutes,	433.20		422.40		
4	5½ minutes,	426.99		411.27		
5	8 minutes,	422.62	C	412.00	D	
6	8 minutes,	440.75		429.25		
7	8 minutes,	311.75		423.00		
8	8 minutes,	432.75		419.87		

The maximum revolutions observed during the run was, starboard engine, 452; port engine, 432; mean, 442, or a speed of 31.4 knots.

The Board was of the opinion that the counter which marks thousands failed to record once during the seventh interval, thereby making the revolutions for that interval 1,000 less than they should be—that is, instead of a mean of 311.75 for the seventh interval, it should be 436.75, making the total mean for the hour of 427.65 instead of the official number of revolutions reported, 419.3. This would give a speed of 30.62 instead of the official speed of 30.13.

Observations were made to determine the change of trim of the vessel at different speeds, as follows: At 30 knots, the change of trim was 45 inches; at 28 knots, 36 inches; at 26 knots, 33 inches; at 20 knots, 9 inches.

The change of trim varied somewhat with the depth of water over the course.

There was no apparent following-wave astern, but large swells travel with the ship at right angles to the course about 50 feet outside the wake. The swells increased in height and length as the depth of water decreased.

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The Board took into consideration the depth of water over the measured course, which varies from 6½ to 15 fathoms. It was found that at speeds of over 24 knots the increase in vibrations and pounding of the propellers in the shoal water was such as to produce a dangerous increase of friction on bearings and strain on the hull in turning, of such a nature that the Board therefore limited the speed in turning to 23 or 24 knots, without shutting off the steam.

Patent logs could not be used to verify the runs on account of the turning necessary on the measured-mile course and the turn during the hour's run.

At low speed very little vibration was observed, but at speeds above 20 knots the vibrations at certain points became excessive, and, as a result, stiffening angles were fitted underneath the main deck just forward of the wardroom hatch, and also four-pound plates just abaft the, propellers were removed and six-pound plates put in, and four stiffening angles extending from frame No. 110 aft were fitted on the outside of the bottom plating. The vibration was maximum at a speed from 20 to 22 knots.

Mackenzie.—The final acceptance trial of this boat was made on December 12, 1898, in the Delaware River.

The weights carried on this trial were as follows:

Articles of load.	Weights required to be carried.	Actual on board.	Additional weights carried to compensate for difference.	
	Pounds.	*Pounds.*		*Pounds.*
Equipment....	8,960	1,978	8 officers	1,200
			24 men	3,600
			Coal in bunkers (extra)	2,182
Ordnance.....	7,840	1,338	Coal in bunkers (extra)	6,502
Coal.....	11,200	11,321	.....	
Total.....	28,000	14,637		13,484

The corresponding draught of the vessel before and after the two-hour run was:

	Before.	After.
Forward,	4 feet 5 inches.	4 feet 3 inches.
Aft,	5 feet 2 inches.	5 feet 0 inches.
Mean,	4 feet 9½ inches.	4 feet 7½ inches.

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The weather was favorable for the trial, there being no wind at first, and only light airs from the southward the latter part of the time. The sky was overcast with occasional light falls of snow. The tide was at high water when the two-hour trial was begun, but soon after the ebb tide made and continued during the run.

The *Mackenzie* left Chester at 9·45 A. M., and, with the members and assistants of the Board, proceeded down the Delaware River. At 10·23 A. M., the vessel, being then below Wilmington, and a short distance above Deep Water Point, the two-hour full-speed trial was begun. During the trial the speed of the vessel was checked by careful observations of known positions on shore, and, allowance being made for the force of the tide, it was evident that the required speed was being obtained. The run was to some four miles below Bombay Hook Light in Delaware Bay, where the turn was made, and the vessel headed again to the northward. An extremely good opportunity of verifying the speed was obtained in twice passing over the distance between Reedy Island Light and Bombay Hook Light, these two runs having been made so near together as to render it probable that no change in force of tidal current had occurred, so that therefore, the tide having been favorable in heading to the southward and contrary in heading to the northward, the force of current could be considered as eliminated in the mean speed. The result agreed most satisfactorily with the speed taken from the standard curve as corresponding to the number of revolutions. The times of passing the various known points on shore, as marked by a chronometer (G. M. T.), was as follows:

	h.	m.	s.
Start above Deep Water Point,	4	53	30
Transit, first range, measured mile,	4	55	27
Transit, second range, measured mile,	4.	58	11
Fort Delaware and Finns Point,	5	19	30
Reedy Island Light,	5	36	00
Bombay Hook Light,	5	59	00
Turn,	6	05	00
Bombay Hook Light,	6	15	00
Reedy Island Light,	6	42	00
End of trial,	6	53	30

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The average number of revolutions for the entire two hours was three hundred and ninety-one and one-tenth (391.1), corresponding to which the standard curve gives a speed of twenty and eleven hundredths (20.11) knots per hour, or eleven hundredths of a knot over the speed required by the contract.

The steering gear was tested at full speed and worked very satisfactorily. The helm was put hard a-starboard in ten (10) seconds, then to hard a-port in sixteen (16) seconds, then to amidships again in ten (10) seconds, the helm moving readily and the boat responding quickly to the motion of the rudder. With an initial list of 4 degrees to port, which the vessel seemed to take up at full speed, the heeling was, helm hard a-starboard, 9 degrees, hard a-port, 2 degrees.

The forward steering gear was thrown out and the after gear and steering wheel connected in four minutes.

The steering gear worked easily, and was very simple in its mechanism. The Board approved heartily of the absence of steam-stearing gear in so small a torpedo boat.

The *Mackenzie's* seagoing qualities, so far as could be judged, were good, and the vibration was no greater than in other torpedo boats under similar conditions of speed. The engines worked very quietly, and the blowers made less noise than in other boats. An approximation of change of trim at the highest speed showed about $5\frac{11}{100}$ feet in length of vessel.

The bow wave of the *Mackenzie* is rather prominent, but in deep water the stern wave is not large; the latter increases rapidly, however, as the water is shoaled.

During the two-hour full-power speed trial the steam pressure was at no time in excess of the maximum working pressure, 250 pounds above the atmosphere, and there was no foaming of the boilers. The throttle valve of the main engine was kept wide open, and was not even partially shut off at any time during the trial. The machinery, both main and auxiliary, functioned very satisfactorily, with the exception of the air pump, whose after piston rod worked loose, becoming unscrewed from its crosshead. There was little vibration in engine frames, and no heating of journals, and no water was used on the engine, ex-

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cept what circulated through the cross head guides. Upon both trials the forward revolution counter broke down and could not be repaired on board. On the occasion of the second, and successful, trial a much more regular pressure of steam was maintained, due to better work on the part of the fire-room force.

The full results of the trial are contained in the report of the engineer member of the Board and the mean results are given in the following statement:

Maximum revolutions,	398.53
Average revolutions,	391.1
Maximum steam pressure at engine, pounds,	248.
Average steam pressure at engine, pounds,	236.2
Maximum air pressure in fire room, inches,	4.75
Average air pressure in fire room, inches,	3.4
Maximum vacuum, inches,	26.
Average vacuum, inches,	24.5
Minimum vacuum, inches,	23.
Speed for the two-hour trial, knots,	20.11
Revolutions corresponding,	391.1

The weight of machinery as far as completed, including water in boiler, condenser, pipes, tanks, etc., is $26\frac{288}{2240}$ tons.

Davis.—The official trial of this boat was made on November 24th, and was successfully continued for the two hours required in the contract without any undue friction of engines or excessive vibration of hull, all parts of machinery and steering gear working smoothly to the end, in so much that the required speed could have been maintained for a further period, in evidence of the good workmanship, adjustments and further endurance of vessels of this class.

The amount of coal to be carried in beginning of trial trip (19,764 pounds) was based upon observed coal consumption, and calculated to insure an average of at least six tons during the two hours' run. Actual results were as follows: Coal on board at beginning of trial, 19,764 pounds; at end of trial, 11,504 pounds; burnt on trial, about 8,250 pounds. Average load of

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coal carried during trial, 15,634 pounds, about 7 tons. A surplus of coal to the credit of the contractors.

The vessel in addition was ballasted, as required by contract, to compensate for unfinished items, etc.

Under these conditions, her observed draught was as follows: Forward, 4 feet 5½ inches; aft, 6 feet 1¾ inches; mean, 5 feet 3⅝ inches; displacement, 126 tons.

The vessel, loaded as described above, proceeded to the free route selected, in the Columbia River, about 12 miles from Astoria, and after some preliminary steaming the official run was begun by signal at 12·13 P. M., and successfully finished at 2·13 P. M. The engines averaged 382 revolutions per minute (23.41 knots). The estimated speed is calculated from the revolutions and official slip of 16⅔ per cent. No patent logs could be used, owing to the continual change of course in following the deepest channel of the river.

The maneuvering qualities of the vessel were satisfactory, as was evidenced by numerous turnings at different speeds. There was no excessive vibration at maximum speed. The maximum vibration occurs just forward and abaft the engine hatches. This is due to the engines being tied to girders under the deck terminating at these points.

Observations made to determine the squat of the vessel relative to the horizon gave results corresponding to previous Board's report, namely: at 382 revolutions, 1½ degrees; at 410 revolutions, 1⅝ degrees. The average squat relative to the surface of the water aft was 5½ inches at 382 revolutions, and 7½ inches at 410 revolutions. These conditions are based upon a constant depth of water. The squat varied with varying depths of water on the course.

CHINA.

Torpedo-Boat Destroyers for China.—These vessels, built by Mr. F. Schichau, of Elbing, for the Imperial Chinese Navy, with their trial load, complete outfit and armament, and with 25 tons of coal on board, are reported by Mr. Schichau to have steamed 35.2 knots over the measured course of 18½ sea miles, and with 67 tons of coal (*i. e.*, full bunkers), 33.6 knots. The

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trials, Mr. Schichau writes, took place in free, open sea, between the Lighthouse Tower at Pillau and that at Brüsterort. During the trial trips the weather was sometimes very windy, and on some trials was even of force 5. This force of wind, however, did not prejudicially affect the speed. The distance between the two lights is 18½ sea miles, and the course was steered by the compass. This course, he states, was covered in 32 minutes 30 seconds, and on one occasion even in 31 minutes 15 seconds. The maximum speed mentioned is 36.7 knots, but it is not stated whether the 35.2 knots, already indicated, is the mean of the runs over the course. All the four torpedo-boat destroyers are said to have made this speed easily, without any effort and without hard work on the part of the stokers. The air pressure was 40 to 45 millimeters, equal to 1.58 inches to 1.77 inches on the water gage. The contract speed was 32 knots. With natural draft the boats made between 30 and 31 knots with 67 tons of coal on board, and with a large supply of water, to give a radius of action of 5,000 sea miles. With the same load on board, and with forced draft, the mean speed on a trial of "several hours" duration was, we are informed, 33.6 knots.

The four torpedo-boat destroyers are 59 meters long, equal to 193 feet 6¾ inches; the beam is 6.4 meters (21 feet), and the displacement 280 tons. The engines, which are balanced on the Schichau system, develop 6,000 indicated horse power. Engines and boat behaved well during the trials, notwithstanding the rough weather experienced.—"Engineering."

ENGLAND.

British Naval Progress.—It is our usual custom, says the London "Engineering" of December 23, to review at the end of the calendar year the progress made with warship building during the preceding twelve months; but as at the time of writing all interest is centered on the new work to be given out by the Admiralty to private contractors, we may depart from our ordinary practice and satisfy some part of the craving for prospective facts regarding these ships before turning to past progress. On December 16 last there were delivered at the

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Admiralty tenders for a new armored cruiser to attain a speed of 23 knots, and on December 20 "bids" were similarly made for the construction of four battleships; while some time ago tenders were submitted for several new 30 to 32-knot torpedo-boat destroyers. This work is not yet given out. The battleships belong to the supplementary naval programme produced in the House of Commons in July, and there are yet four cruisers under this supplementary programme to be ordered, but the designs are not completed. The large cruiser was included with three others in the original Government programme of February last—a cruiser of the Cressy class has been ordered from Clydebank, another from Vickers' Naval Construction Works, at Barrow-in-Furness, and now the order for the larger cruiser is pending while her consort is to be built at the Pembroke Dockyard.

Taking the battleships, it may be said that they belong to a new class, but are more like the *Formidable* than the *Canopus*. Table I gives the leading particulars of all three classes, as well as of the *Majestic* type, with a note of the number built or projected. Table II refers to cruisers, while Table III gives the principal data of the official trials made in 1898.

H. M. S. Formidable.—This vessel, the launching of which on November 17, 1898, was noted in our last issue, is one of three designed by Sir William White as improved *Majestics*. She is 10 feet longer than the latter, and, while displacing 100 tons more, will have a draught of 9 inches less.

The leading dimensions are as follows: Length between perpendiculars, 400 feet; beam, 75 feet; mean draught, 26 feet 9 inches; displacement, 15,000 tons. She will be fitted with two sets of triple-expansion engines having collectively 15,000 I.H.P., and are to maintain a speed of 18 knots. Steam will be supplied by twenty Belleville boilers, working at a pressure of 300 pounds reduced to 250 pounds at the engines. Even with the less draught these vessels will carry 2,100 tons of coal, provision being made to coal the lower bunkers independently of the upper ones. The side armor is 9 inches thick, 15 feet deep, and 216 feet long, and is treated with the Harveyized process. The bulkheads are 9 to 12 inches thick and join the side armor, thus

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TABLE I.—BRITISH BATTLESHIPS BUILT, BUILDING OR PROJECTED.

Type and date.	*Majestic* (1895).	*Canopus* (1897).	*Formidable* (1898).	New ships (1899).
Number included	Nine *	Six	Six	Four
Length between perpendiculars	390 feet	390 feet	400 feet	405 feet
Breadth	75 feet	74 feet	75 feet	75 feet 6 inches
Draught (medium)	27 feet 6 inches	26 feet	26 feet 9 inches	26 feet 6 inches
Displacement	14,900 tons	12,950 tons	15,000 tons	14,000 tons
Speed in knots	17.5	18¼	18	19
Indicated horse power	Nat., 10,418; for., 12,497	Natural, 13,500	Natural, 15,000	Natural, 18,000
Cylinders	40. in., 59 in., 88 in.	30 in., 49 in., 80 in.	31½ in., 51½ in., 84 in.	33½ in., 54½ in., 63 in., 63 in.
Stroke	51 inches	51 inches	51 inches	48 inches
Revolutions	106 †	108	108	120
Piston speed	901 feet	918 feet	918 feet	960 feet
Working pressure	155 pounds	300 lbs. to 250 lbs.	300 lbs. to 250 lbs.	300 pounds to 250 pounds
Boilers, number and type	8 S. E. cylindrical	20 Belleville	20 Belleville	24 Belleville
Heating surface	25,570 square feet	33,793 square feet	37,120 square feet	43,260 square feet
Grate area	821 square feet	1,050 square feet	1,170 square feet	1,375 square feet
Heating surface per I.H.P.	F. D. 2.04, N. D. 2.45 sq. ft.	2.50 square feet	2.475 square feet	2.4 square feet
I.H.P. per sq. ft. of grate area	F. D. 15.22, N. D. 12.68	12.85	12.8	13.1
Weight of machinery	1,300 tons	1,290 tons	1,400 tons	1,580 tons
Armament	Five tubes, four submerged, four 12-in. b. l. guns, twelve 6-in. q. f., eighteen 12-pounders, twenty smaller guns.	Four sets of torpedo tubes, 18 in., four 12-in. b. l. guns, twelve 6-in. q. f., ten 12-pounder q. f., and eighteen smaller guns and Maxims.	Two submarine torpedo tubes, 18 in. diam., four 12-in. b. l. guns, twelve 6 in. q. f., eighteen 12-pdrs., and twenty smaller guns.	Four sets of submerged 18 in. tubes, four 12-in. b. l. guns, twelve 6 in. q. f., twelve 12-pounder q. f., and other smaller guns and Maxims.
Armor	Belt, 9 inches Bulkhead, 14 in. to 9 in. Barbette, 14 in. to 6 in.	6 inches 12 inches 12 inches to 5 inches	9 inches 12 inches to 9 inches 12 inches to 6 inches	7 inches to 4 inches 11 inches to 10 inches 10 inches to 7 inches

* All commissioned.

† Actual run on forced-draft trial for 12,497 indicated horse power.

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TABLE II.—BRITISH CRUISERS BUILDING OR PROJECTED.

Class.	*Argonaut* class.	*Cressy* class.	*Powerful* class.	New cruisers.
Number	Eight	Six	Two	Two
Length between perpendiculars	435 feet	440 feet	500 feet	500 feet
Breadth	69 feet	69 feet 6 inches	71 feet	71 feet (extreme)
Draught	24 feet 7 inches	26 feet 3 inches	27 feet	26 feet
Displacement	11,070 tons	12,000 tons	14,200 tons	14,100 tons
Speed in knots	20¾.	21	22¼	23
Indicated horse-power	18,000	21,000	25,000	30,000
Cylinders	34 in., 55½ in., 64 in., 64 in.	36 in., 59 in., 68 in., 68 in.,	45 in., 70 in., 76 in., 76 in.,	43½ in., 71 in., 81½ in., 81½ in.
Stroke	48 inches	48 inches	48 inches	48 inches
Revolutions	120	120	114.4	120
Piston speed	960	960 feet	915 feet	960 feet
Working pressure	300 to 250 pounds	300 to 250 pounds	260 to 210 pounds	300 to 250 pounds
Boilers, number and type	30 Belleville	30 Belleville	48 Belleville	43 Belleville
Heating surface	47,300 square feet	51,500 square feet	69,576 square feet	71,970 square feet
Grate surface	1,390 square feet	1,650 square feet	2,193.6 square feet	2,310 square feet
Weight of machinery	1,630 tons	1,800 tons	2,258 tons	2,500 tons
I.H.P. per ton	11.6	11.67	11.08	12.00
Square feet of heating surface per I.H.P.	2.5 square feet	2.45	2.79	2.4
I.H.P. per square foot of grate area	13.6	12.7	11.4	13.0
Armament	Two submerged torpedo tubes 18 inches in diameter, sixteen 6-inch quick-firing, fourteen 12-pounder quick-firing and three 3 pounder quick-firing guns.	Two submerged torpedo tubes 18 inches in diameter, two 9.2-inch breech-loading, twelve 6-inch quick-firing, and seventeen smaller guns.	Four tubes, two 9.2-inch breechloading, twelve 6-inch quick-firing, and thirty smaller guns.	Same as *Powerful*

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TABLE III.—OFFICIAL RESULTS OF TRIALS OF BRITISH BATTLESHIPS AND CRUISERS MADE IN 1898.

Name of ship.	Type.	Thirty hours' coal consumption trial.			N. D. trial, or thirty hours' coal consumption trial at higher powers.			Full-power trial.		
		I.H.P.	Speed.	Coal per horse power hour.	I.H.P.	Speed.	Coal per horse power hour.	I.H.P.	Speed.	Coal per horse power hour.
			Knots.	*Pounds.*		*Knots.*	*Pounds.*		*Knots.*	*Pounds.*
Illustrious	Battleship	6,155	14.51*	1.77	10,241	55.96*	.....	12,126	15.5*	.....
Furious	Fleet cruiser	2,260	13.6	2.34	7,133	18.7	2 1	10,272	20.1	.....
Vindictive	Fleet cruiser	2,153	12.6*	2,16	7,164	17.7*	1 83	10,263	20.1*	.....
Proserpine	Third-class cruiser	3,643	17.0*	2.4	5,336	19.7*	.....	7,145	21.0*	.....
Perseus	Third-class cruiser	3,627	17.2*	2.1	5,243	18.9*	.....	.....	.....	.....
Pegasus	Third-class cruiser	3,698	17.26*	1.96	5,400	20.0*	.....	7,134	21.2*	.....
Pactolus	Third-class cruiser	3,631	16.6*	2.46	5,428	19.1*	.....	7,201	20.5*	.....
Diadem	First-class cruiser	3,318	12.64*	2.21	12,813 12,862†	19.53	1.61 1.88	17,262 15,903	20.65	1.77 .....
Europa	First-class cruiser	3,319	12.9*	2.23	12,770 12,705†	....	1.94 2.01	17,026 16,314	....	1.91 .....
Niobe	First-class cruiser	3,348	12.0*	1.76	12,968	19.27	1.55	16,822	20.50	1.66
Andromeda	First-class cruiser	3,388	12.9*	1.98	12,621	19.3	1.74	16,751	20.41	1.7
Argonaut	First-class cruiser	3,756 3,815	13.15	2.13 2.02	13,815	19.86	1.6	18,894	21.17	1.6

The *Illustrious* is the only vessel on the list with cylindrical boilers; the four third-class cruisers of the "P" class have small tube boilers—the *Proserpine* of the Thornycroft design, the *Perseus* of the Yarrow type, the *Pegasus* of the Reed design, and the *Pactolus* of the Blechynden patent. All these vessels had forced draft on the full-power trial. The other ships have the Belleville type, the *Furious* and *Vindictive* without economizers. The *Diadems* have such economizers, and all these attained their full power with natural draft.

* Speeds marked with an asterisk were taken by log; the others on the deep-sea Admiralty course on the Cornish coast. The low speed on full-power trial of *Illustrious* was due to the state of the sea.

† These trials—*Diadem* and *Europa*—were with only 78 per cent. of the boiler power.

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forming a belt around the vitals of the ship. There are two protective decks 2.5 to 4 inches in thickness.

The armament consists of four 12-inch breech-loading wire-wound guns, two firing forward and two aft. These guns are in barbettes of 14 inches of steel, and the positions further protected with strong shields. The auxiliary armament is formed of twelve 6-inch rapid-fire guns of a new type, mounted in casements, eight on the main deck and four on the upper deck. In addition, sixteen 12-pounder rapid-fire guns are mounted, eight on the main deck and eight on the upper deck. Two 12-pounder boat guns, twelve 3-pounder rapid-fire guns and eight machine guns.

The 13-inch gun of the United States ordnance throws a larger projectile than the 12-inch wire-wound gun of the British ordnance. The 13-inch projectile weighs 1,100 pounds, against 850 for the 12-inch gun. The muzzle velocity of the 13-inch projectile is 2,100 foot-seconds, and of the 12-inch gun 2,367 foot-seconds. The perforation of the 13-inch gun at the muzzle is 33.5 inches of iron, and of the 12-inch gun 36.8 inches of iron.

There will be four 18-inch submerged torpedo tubes, two being fitted forward and two aft. In order to obviate any serious injury arising from the use of the ram, which is a steel casting weighing more than 30 tons, the sides forward are partly covered with a 2-inch nickel plating in addition to the ordinary skin plating, this stiffening extending from the ram to the belt.

H. M. S. Irresistible, a first-class, twin-screw, barbette battleship, was launched December 15, 1898, at Chatham. She is one of three big battleships now in course of construction, the other two being the *Formidable* and *Implacable*, which are respectively Portsmouth and Devonport ships. These vessels are to be each of 15,000 tons displacement, and are, therefore, just 100 tons heavier than the *Majestic* class, and no less than 850 tons above the *Royal Sovereign* class, which were the monsters of a few years ago. The *Irresistible* is 400 feet long between perpendiculars, and 75 feet extreme breadth. The draught of water is to be 20 feet 3 inches forward and 27 feet 3 inches aft. The coal at load draught is 900 tons, but there is a capacity for stowage

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of 2,040 tons. Not many details have been made known respecting these big armorclad ships. The speed with natural draft is estimated at 18 knots, which is to be obtained with 15,000 indicated horse power. The engines are by Messrs. Maudslay, Sons & Field, and are of the now universal inverted three-stage compound type, supplied with steam by Belleville boilers, of which there will be twenty.

H. M. Cruiser Andromeda.—This vessel, which is one of the *Diadem* class of cruisers, is 435 feet long by 69 feet beam, and has a displacement of 11,000 tons on a draught of 26 feet. The propelling machinery, which has been constructed by Messrs. R. and W. Hawthorn, Leslie and Co., Ltd., of St. Peters, is of 16,500 indicated horse power. The twin-screw engines are of the four-crank triple-expansion type, each set having one high, one intermediate and two low-pressure cylinders, the diameters being 34 inches, 55½ inches, and two of 64 inches by 48-inch stroke. Steam is supplied by thirty boilers of the Belleville type, fitted with economizers. These boilers have a total heating surface of 40,140 square feet. The condensers, which are of gun metal, have a cooling surface of 17,500 square feet. The whole of the shafting is of hollow steel, the propellers being of gun metal. The boilers work at a pressure of 300 pounds per square inch, which is reduced at the engines, by means of Belleville reducing valves, to 250 pounds. The trials stipulated by the contract were three in number, namely: One of 30 hours duration at 3,300 I.H.P.; one of 30 hours duration at 12,500 I.H.P.; one of 8 hours duration at the full power of 16,500 I.H.P. The whole of these trials passed off without the slightest hitch of any kind, the contract conditions in all cases being more than realized. The following is a list of the results obtained: First 30-hours trial: I.H.P. 3,388; revolutions, 69¼; speed, 12.76 knots; coal consumption per I.H.P. per hour, 1.98. Second 30-hours trial: I.H.P., 12,621; revolutions, 107; speed, 19.31 knots; coal consumption per I.HP. per hour, 1.74. Eight-hours full-power trial: I.H.P., 16,750; revolutions, 117; speed, 20.4 knots; coal consumption per I.H.P. per hour, 1.76. The *Andromeda* was built at H. M. Dockyard,

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Pembroke, but went round to Portsmouth to be completed and to receive her armament.

Steam Trials of H. M. S. "Ariadne."—This first-class protective-deck cruiser of the improved *Diadem* class, built and engined by the Clydebank Engineering and Shipbuilding Company, Limited, on the Clyde, completed on Tuesday, the 7th February, 1899, a series of contract steam trials. The *Ariadne*, so far as the hull is concerned, in which which we include offensive and defensive qualities, resembles closely the *Diadem* class, and the only difference is in the boilers. The boilers of the later ships have been designed with slightly more heating surface than the *Europa*, 47,300 square feet of heating surface, and 1,390 square feet of grate area, the ratio being 34.0 to 1; while in the case of the *Europa*, with the same number of boilers, the ratio is 27.73 to 1, the heating surface being 40,600 square feet, and the grate area 1,450 square feet. It will be seen that the coal burned per square foot of grate per hour is higher. On the full-power trial it was nearly 22 pounds per square foot of grate, as against 21 pounds in the *Diadem* class. The power per square foot of grate was 13.2 indicated horse power, as against 11.63 indicated horse power in the *Europa;* but in special trials both these results have been exceeded. The heating surface is equal to 2.48 square feet per unit of power maintained; in the *Europa* it was 2.38.

In each type of ship there are thirty Belleville boilers, with economizers. The engines are of the triple-expansion type, but the arrangement in the *Ariadne* differs from that in the *Europa*. Instead of the four cylinders being placed as follows from the bow end, high-pressure, intermediate pressure, and the two low-pressures with the valves between each, the order is as follows: low-pressure slide valve, low-pressure cylinder, high-pressure cylinder, high-pressure piston valve; intermediate-pressure piston valve, intermediate pressure cylinder, low-pressure cylinder and low-pressure piston valve. Thus the cylinders are in pairs as closely together as is possible, and the sequence of cranks is, high pressure, intermediate pressure, forward low pressure, after low pressure, the first and third named being at right angles, as

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are the other two. This arrangement gave practically no vibration. The diameters of cylinders are 34 inches, 55½ inches, 64 inches and 64 inches, by 48 in stroke. They were designed to give the full power at 120 revolutions, while in the case of the *Europa* the designed speed was 110 revolutions, although with 112.4 revolutions 17,010 indicated horse power was got, while the *Ariadne* got 19,156 indicated horse power with 118.9 revolutions.

RESULTS OF STEAM TRIALS OF H. M. S. *ARIADNE*.

Description of trial		30 hours' coal consumption at 3,600 I.H.P.		30 hours' coal consumption at 13,500 I.H.P.		8 hours' full power		
When tried		Jan. 31 and Feb. 1, 1899.		February 3 and 4, 1899		February 6, 1899		
Draught of water	Forward	25 ft. 5 in.		24 ft. 8½ in.		24 ft. 3 in.		
	Aft	26 ft. 2 in.		25 ft. 11½ in.		26 ft. 3 in.		
Displacement		—		—		—		
Actual load on safety valves, pounds		300		300		300		
Pressure of air in stokehold, in. of water		...		...		.23		
Average pressure at boilers		218		262		288		
Average pressure at engines		202		227		240		
Receiver pressures	H.P.	143.5		206.5		229		
	I.P.	34.5		58.5		75.5		
	L.P	5		18		24.5		
Average vacuum		24.8		25.5		25.3		
Mean pressure in cylinders	H.P.	20.6	17.7	84.2	87.5	103.4	104.7	
	I.P.	17.3	18.1	32.9	33.1	40.3	41.9	
	L.P. forward	7.8	8.3	16.3	16.7	21.3	21.1	
	L.P. aft	7.6	7.3	17.4	16.4	22.6	20.9	
Mean number of revolutions per minute		70.3		109.1		118.9		
Indicated horse power, total		3,758		14,046		19,156		
Speed, knots		13.3		20.1		21.5		
Force of wind		2 to 3		1 to 6		2 to 3		
State of sea		Slight swell		Smooth to moderate		Moderate swell		
Propeller	Diameter	17 ft.		—		—		
	Pitch	21 ft. 6 in.		Same		Same		
Consumption per indicated horse power per hour		2.05		1.73		1.66		

The *Ariadne* is 435 feet long between perpendiculars, 69 feet beam, and at 24 feet 7 inches draught has 11,070 tons displacement.

Steam Trials of H. M. S. Argonaut.—The first-class cruiser *Argonaut*, built and engined by the Fairfield Shipbuilding and

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Engineering Company, Limited, Govan, has completed her series of contract trials with very satisfactory results, as the appended table shows. She is of similar design to the four vessels of the *Diadem* class, and is the first of a second quartette, including the *Ariadne*, delivered to the Admiralty recently by the Clydebank Company, the *Amphitrite*, ready at Vickers' Works at Barrow-in-Furness, and the *Spartiate*, in progress at the Pembroke Dockyard. The boilers have slightly more surface than those of the *Diadem*, and the engines, although of the same dimensions, are required to work at 120 revolutions, instead of 110 per minute, and to develop 18,000 indicated horse power, against 16,500 indicated horse power, giving the ship a speed of 20¾ knots as compared with 20½ knots. As a matter of fact, the *Argonaut's* machinery on the full power worked at a mean of 128.4 revolutions, developed 18,894 indicated horse power, and gave the ship when down to her designed draught, a speed of 21.17 knots, instead of 20.75 knots. The *Argonaut*, it may be well to state, is 435 feet long, 69 feet beam, and 24 feet 7 inches draught, at which the displacement was 11,000 tons. The engines are of the four-crank type, but working triple-compound, the diameters of cylinders being 34 inches and 55½ inches with two of 64 inches, a stroke of 48 inches, so that the full power required a piston speed of 1,027 feet per minute. The vessel has thirty Belleville boilers with economizers, the total heating surface being 47,300 square feet, and of grate area 1,390 square feet, so that on the full-power trial the power was equal to 13.6 units per square foot of grate, while the ratio of heating surface to power was 2.5 square feet to 1 of power.

This total power of 18,894 indicated horse power was made up as follows :

Mean indicated horse power	High	2,891	2,869
	Intermediate	2,413	2,510
	Forward, low	1,988	1,921
	Aft, low	2,319	1,983
	Total	9,611	9,283
	Grand total	18,894	

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RESULTS OF STEAM TRIALS OF H. M. S. *ARGONAUT*.

Description of trial		30 hours' coal consumption at 3,600 I.H.P.		30 hours' coal consumption at 13,500 I.H.P.		8 hours' full power		30 hours' coal consumption at 3,600 I.H.P.
When tried		Nov. 25 and 26, 1898		Nov. 29 and 30, 1898		December 3, 1898		Dec. 7 and 8, 1898
Draught of water	Forward	24 feet 3 inches		Same		Same		Same
	Aft	26 feet 3 inches						
Displacement, tons		...		...		...		...
Actual load on safety valves, pounds		300		300		300		300
Pressure of air in stokehold, inch of water		...		...		.21		...
Average pressure in boilers		226		Variable		293		Variable
Average pressure at engines		133		Variable		...		Variable
Receiver pressures	H.P.	135		Variable		238		Variable
	I.P.	40		Variable		94		Variable
	L.P.	8		Variable		23		Variable
Average vacuum		25.1		26.6		25.6		26
Mean pressure in cylinders	H.P.	35.7	34.5	85.2	83.5	102.1	101.9	36.9	33.9
	I.P.	10.7	10.6	24.8	26.3	31.9	33.5	11.8	13.1
	L.P. For'd.	7.1	6.6	16.4	15.3	19.8	19.2	6.4	6.4
	L.P. Aft.	7.9	7.3	18.6	16.3	23.1	19.9	6.8	5.9
Mean number of revolutions per minute		74.6		116		128.4		75.9
Indicated horse power (total)		3,756		13,815		18,894		3,815
Speed, knots		13.15		19.86		21.17		...
Force of wind		4 to 7		1 to 5		...		3 to 7
State of sea		Smooth		Smooth		...		Moderate to slight
Propeller	Diameter	17 feet		...		...		...
	Mean pitch	S. 20 feet $5\frac{7}{16}$ inches P. 20 feet 6 inches		Same		Same		Same
Consumption per indicated horse power per hour		2.13		1.6		1.62		2.02

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This was realized, as indicated in the table above, by only 0.21 inch of pressure indicated on the water gage, and it will be remembered that in the old cylindrical-boiler days anything under 0.5 inch was considered natural draft. The rate of combustion on this trial was 21.9 pounds per square foot of grate. This, of course, has been excelled in the Navy with the Belleville boiler; it may be remembered, for instance, that the *Diadem*, in her special trials, realized 14.11 indicated horse power per square foot of grate, 1.99 square foot of heating surface being sufficient for each horse power, the coal burned per square foot of grate being 27.52 pounds. And even then the pressure was only 0.3 inch. The *Argonaut* has thus much in reserve, even when doing 18,894 indicated horse power and 21.17 knots, nearly half a knot in excess of the design. This speed, like all the rates at various powers, was determined by four runs on the deep-sea course between Rame Head and Dodman Point, when the vessel was at her full load displacement. The full power realized, it may be said, is equal to 11.6 indicated horse power per ton weight of all machinery, which, with the liberal boiler and bearing-surface allowances, is a very satisfactory result, and on it Sir John Durston is to be congratulated.

H. M. Torpedo-Gunboat Sheldrake has just completed a series of most interesting trials on her boilers. The basin trials of this vessel took place at Devonport on the 14th, 15th, 16th and 17th November, and the sea trials were carried out off Plymouth on November 28 and December 1. There are four boilers in this ship of the well-known Babcock and Wilcox type, having a collective heating surface of 9,424 square feet, and a total grate area of 252 square feet. 4,050 I.H.P. was obtained on the sea trials when burning about 25 pounds of coal per square foot of grate per hour with ½-inch air pressure in the ashpits; with this power the vessel obtained a speed of 20.6 knots per hour on a coal consumption of 1.57 pounds per I.H.P. per hour. When burning only 15 pounds of coal per square foot of grate per hour, the average I.H.P. was 2,642; the speed obtained with this power was 17.9 knots per hour, and the coal consumed per I.H.P. per hour was 1.42 pounds.

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English Torpedo Boat Trials.—The London correspondent of the "Glasgow Herald" furnishes some interesting results of trials of torpedo-boat destroyers during the year 1898, and in opening his article briefly notes the extent of the progress made with the fleet of boats ordered. There were, he says, forty-two in the first fleet of 27-knot boats, and three of these, by White, of Cowes, passed through their trial with about a tenth of a knot to spare, although the power was somewhat abnormal, between 4,800 and 5,070 indicated horse power. Two, built at Paisley, have yet to pass through the ordeal—they are being fitted with water-tube boilers; and the others have had long periods of commission, and have done well, although water-tube boilers have had to be ordered for some of the first, which had locomotive boilers. Fifty-four faster vessels were ordered, including four of 32 knots or more, the *Arab*, from Clydebank; the *Albatross*, from Thornycroft; the *Express*, from Laird; and the *Viper*, from Fairfield. The other fifty were to steam 30 knots, and of these fifteen have passed through their trial during the year just closed, fourteen succeeded the previous year, and there remain twenty-one of the 30-knot and the four faster boats still to try, of which five have not yet been launched. Last year Laird, Fairfield and Palmer each passed three through their runs. Vickers, of Barrow-in-Furness, Doxford, of Sunderland, and Thornycroft, of London, have each succeeded in the trials of two boats. The power necessary has varied very much. The lowest was with one of Thornycroft's boats, 5,892 indicated horse power, which gave almost the highest speed got, 30.4 knots; while Vickers, with the *Avon*, about equaled this with 5,986 indicated horse power and 30¼ knots, the sister boat from the Barrow works doing 30.35 knots for 6,412 indicated horse power.

The highest power was registered in one of Laird's boats, which developed 7,090 indicated horse power, and only got a small fraction over 30 knots. Another of the same builder's boats registered 6,848 indicated horse power for 30.16 knots; but a third made 30¼ knots for 6,146 indicated horse power. Thornycroft's powers are low; the others, with one or two exceptions, range about 6,000 indicated horse power upwards. The

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highest speed last year was with the *Aerial*, Thornycroft's boat, 30.6 knots; next Palmer's *Flying Fish*, 30.48 knots; Palmer's *Fawn*, 30.46 knots; Thornycroft's *Angler*, 30.40 knots; *Barrow's Bittern*, 30.35 knots; Fairfield's *Osprey*, 30.31 knots; Laird's *Wolf*, 30.26 knots; Vicker's *Avon*, 30.25 knots, and Fairfield's *Gipsy* and *Fairy*, 30.20 knots. As to coal consumption, the lowest return was in the case of the *Aerial*, 2.02 pounds; but this was exceptional, and, moreover, extreme accuracy in this respect under the trying conditions is difficult of attainment. As a rule, the slightest fraction under the stipulated 2½ pounds is satisfactory, and in one or two cases it was more, necessitating an extra load, which placed some of the ships at a slight disadvantage as to speed. Two of the 32-knot boats have had frequent preliminary trials, but none have pulled off their speed. The *Albatross* has done 31¼ with 7,500 indicated horse power, and it is hoped 32 knots will be got; but it will probably need more than the assumed 8,000 indicated horse power, which means a piston speed of 1,340 feet per minute, with over 4,000 revolutions per minute. Meanwhile Yarrow has passed through a preliminary trial the first of his Japanese boats, and got 31 knots for a trifle over 6,000 indicated horse power.—"Naval and Military Record."

FRANCE.

New Armored Cruisers.—The new first-class triple-screw armored cruisers *De Gueydon*, *Dupetit-Thouars* and *Montcalm* are to be vessels of the following dimensions: Length between perpendiculars, 448 feet 6 inches; extreme beam, 62 feet 9 inches; depth of hold, 22 feet 6 inches; mean draught, 22 feet 9 inches; displacement, 9,500 tons; coal stowage, 1,025 tons.

As in the *Jeanne d'Arc*, the protection consists of a cellular space comprised between the two armored decks, covered on the outside by an armor belt in two streaks; the lower of which, 6 inches in its thickest part at the water-line, but tapering off below and toward the extremities of the ship, extends from 4 feet 9 inches below the water line to 1 foot above; the upper belt, 3.8 inches thick, extends from the upper edge of the lower belt to the upper armor deck, except forward, where it is carried

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right up to the forecastle deck, while aft it stops immediately abaft the rudder, the two ends being joined by a transverse armored bulkhead, which reaches to the double bottom. Two other armored bulkheads, one before the after turret, the other abaft the foremost one, shut in the central battery on the upper deck. The lower armored deck, which is nearly on a level with the water line amidships, is 1.2 inches thick on the central flat part and 2 inches thick on the slopes, which extend to the lower shelf of the armor belt; the upper armored deck is formed of two ½-inch plates of hardened steel. The cellular cofferdam is similar to that in the *Jeanne d'Arc*, and is formed by two longitudinal water-tight bulkheads; the space enclosed between the first of these and the ship's side is divided into numerous compartments filled with cellulose, while the space between the two bulkheads serves as a collector for the water which may come through the armor and cofferdam, numerous water ways being fitted to conduct this water to the hold. The large space enclosed between the two inner bulkheads is also subdivided as much as possible, while all the trunks leading through it, funnels, ammunition tubes, ventilators, etc., are protected by armored combings and a cofferdam. The superstructures differ a little from those of the *Jeanne d'Arc*, the spar deck being continued almost right aft, while the turret for the after 19-centimeter gun is raised above it instead of being on the upper deck, as in the earlier ship. The bridges also not so large, there being only a small one between the after funnel and the mizenmast, and a somewhat larger one between the two foremost funnels and the foremast, round which it is carried, on it before the mast being the armored conning tower, the chart house, and look out places.

The armament of these ships will consist of two 19.4 centimeter (7.6-inch) guns in armored turrets, one forward and one aft, eight 16.4-centimeter (6.4-inch) quick-fire guns in armored casemates, four 10-centimeter (3.9-inch) quick-fire guns on the spar deck, sixteen 3-pounder quick-fire guns distributed in the tops and other parts of the ship, and six 1.5-pounders with two submerged torpedo tubes. The eight 16.4-centimeter quick-fire guns are mounted two forward and two aft in the angles of the case-

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mate, with an arc of training which enables them to be fired from right ahead and right astern to the beam respectively, the remaining four being mounted on the broadside. The casemates are protected exteriorly by steel plates extending from the upper to the spar deck, their internal faces, as well as the roofs and platforms, being also made of hard steel armor; the carriages of the gun are also fitted with steel shields, so that the open part of the gun port is reduced to a minimum. The 10-centimeter quick-fire guns are protected by two shields, one fixed, the other moving with the gun. The ammunition tubes for the two 19.4-centimeter guns lead straight up into the turrets, those for the smaller guns lead up inside the cofferdam to the casemate.

The ships are to be driven by three screws; the engines, each in a separate compartment, develop together 19,600 I.H.P., which is to give under forced draft a speed of 21 knots. The *Montcalm* is to be provided with twenty Normand-Sigaudy water-tube boilers, the *Dupetit Thouars* twenty-eight Belleville, and the *De Gueydon* twenty-five Niclausse. The ships will be lighted and the guns and ammunition hoists worked by electricity, which will be provided by four dynamos. The normal provision of coal is 1,025 tons, which will give a radius of action at 10 knots of 6,500 miles, or of 1,230 miles at full speed. With all reserve places filled with coal, the radius at 10 knots is increased to 10,300 miles, and at full speed to 1,920; or they can run at full speed for 61 hours with their normal coal supply and for 90 hours with the extreme limit of stowage. The "Yacht" complains that in this class of vessel the coal supply and consequent radius of action is too small, and that the guns in the central redoubt are insufficiently protected.—"Le Yacht" and "Le Temps."

French submarine torpedo boats.—Lieutenant Darefus, of the French Navy, has been at work for the past eight years on boats of this type, and six of his designs are to be built in 1899. These boats are not fully described, but they are to be 111 feet long, 12 feet beam, 5 feet maximum draught on surface, 106 tons displacement, and the 217-H.P. engines will operate a single screw and drive the vessel at a 12-knot speed at the surface. These boats will be identical with the *Narval*, now build-

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ing at Cherbourg. They are to have a surface-steaming radius of 250 knots, and an underwater radius of 100 knots at a 10-knot speed. On the surface they will be propelled by steam, and by electric accumulators below the surface, with dynamos on board to charge the accumulators. One of them, the *Zede*, has been tested at Toulon, and is said to have made an underwater trip of 40 miles.

GERMANY.

Kaiser Frederick III has recently made successful trial trips. She was the first of the five first-class battleships built under the new programme, and is a triple-screw ship of 11,130 tons displacement. Her dimensions are: Length, 377 feet 4 inches; beam, 67 feet; draught, 25 feet 8 inches. Protection is afforded by an all-around water-line belt of hardened steel 11.8 inches thick, tapering away at the bow and stern, and a 3-inch armored deck.

The main battery consists of four 9.2-inch guns of newest pattern, mounted in two Harveyized steel turrets, one fore and one aft, of 9.8-inch thickness. The secondary battery contains eighteen 5.9-inch, twelve 3·3-inch, twelve 1.4-inch quick-fire guns and also twelve 3-inch machine guns. The 5.9-inch quick-fire guns are protected either by turrets or casemates.

The engines for each of the three screws are in their own separate water-tight compartment. These engines were built by the Government establishment at Wilhelmshaven.

There are eight cylindrical boilers and four water-tube boilers.

On forced-draft trial the engines developed 13,500 I.H.P., or 500 H.P. over contract, making 115 revolutions per minute and securing a speed of 18 knots, although a heavy sea was running at the time.

Baiern.—This battleship made a six-hours forced-draft trial lately, developing 6,386 I.H.P. for a speed of 15.5 knots average.

Freya.—This new second-class cruiser has also completed a satisfactory, full-speed trial, developing 10,500 I.H.P., and making 20 knots average speed. She is fitted with Niclausse water-tube boilers.

RUSSIA.

The Russian naval programme is, according to a published statement by Lord Charles Beresford, as follows: One

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hundred and seventeen million dollars is to be expended during the period of 1898–1904 upon the construction of eight first-class battleships, six first-class cruisers, ten second-class cruisers, one submarine transport, one torpedo transport, twenty torpedo-boat destroyers and thirty torpedo boats. The battleships will all be of 12,900 tons, 368 feet in length, 72 feet 6 inches beam and 26 feet draught, and to have a speed of 18 knots under natural draft. One is being built by the Cramps at a contract cost of $4,358,000, to be delivered in thirty months; four are being built at the Government yards in Russia, one in France, and two are still unassigned. Of the first-class cruisers of 6,000 tons and 23-knot speed, Cramps are building one, two have been placed in France, two are being built by a Belgian firm at Nicolaieff, and builders in Germany have been invited to bid on the remaining large cruiser and one of the 3,000-ton cruisers, of which latter nine are still to be assigned. Six torpedo-boat destroyers of 312 tons are building at the Neroskey Works, St. Petersburg, and six of the same size in France; they are all to have a speed of 29 knots under natural draft. German shipyards have been offered a chance to bid on eight boats of 350 tons. Finland is building four 150-ton torpedo boats to steam 29 knots under forced draft, and the remainder will be built in Russian yards. The total of this naval programme is seventy-six vessels of 199,744 tons. There is quite a number of battleships and cruisers not yet placed, and the builders of the *Oregon* should have an opportunity to compete with Eastern and foreign shipbuilders and furnish vessels to serve as samples of what constitutes efficiency in working and in construction.

JAPAN.

Chitose.—The protected cruiser *Chitose*, built by the Union Iron Works, San Francisco, for the Imperial Japanese Navy, exceeded all expectations. On her official trial she made a six-hour run over the course in Santa Barbara channel, averaging 21.048 knots per hour, whereas but 20.5 knots are required, and developing a maximum speed of 21.38 knots under natural draft. On her forced-draft trial just completed, she averaged 22.87

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knots per hour for two hours, the highest speed being 23.76 knots. The contract calls for the maintenance of only 22.5 knots during two consecutive hours.

The data as to horse power and efficiency of propeller has not been completely worked out, but the indications are that with less than 135 revolutions the vessel will make 20.5 knots. Evolution tests made under full speed were very successful, the *Chitose* turning in a radius of 300 feet, and being stopped from full headway to going astern within her own length.

The contract for the *Chitose* was signed at Washington, D. C., December 31, 1896. The first piece of keel was laid May 1, 1897. The first rivet was driven June 26, 1897, and the vessel was launched January 22, 1898. It is expected that she will be ready for her trial some time this month (January, 1899). Principal dimensions and other particulars of the vessel are as follows:

Length over all, feet and inches	405.2
Length, load-water line, feet and inches	396.0
Length, between perpendiculars, feet and inches	376.5
Breadth, moulded, feet and inches	49.0
Draught, normal, feet and inches	17.7½
Displacement, tons	4,760
Speed, knots	22½
I.H.P.	15,500
Coal capacity (total) tons	1,000

Engines, twin screws; one four-cylinder triple-expansion engine on each screw.

H.P. cylinder, diameter, inches	40
I.P. cylinder, diameter, inches	60
Two L.P. cylinders, diameter, each, inches	66
Stroke, inches	36
Revolutions per minute	150

Piston valves on H.P. cylinder; slides on I.P. and L.P.; cast-steel bed plates; forged-steel framing.

Main boilers.—Twelve single-ended, cylindrical, four-furnace boilers. Working pressure, 155 pounds.

ONE BOILER.

Mean diameter, feet and inches	14–0
Length over heads, feet and inches	9–3¾
Number of furnaces	4

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Diameter of furnaces { Least, feet and inches	2-10
Diameter of furnaces { Greatest, feet and inches	3-2
Thickness, inch	$\frac{1}{2}$
Number of combustion chambers to each boiler	2.
Thickness of combustion-chamber sheets, inch	$\frac{9}{16}$
Heating surface:	
Four hundred and thirty $\frac{1}{4}$-inch charcoal-iron tubes, square feet	1,540.8
Four furnaces, square feet	140.2
Two combustion chambers	248.0
Heating surface, one boiler, square feet	1,929.
Heating surface, twelve boilers, square feet	23,148.
Area through tubes, one boiler, square feet	9.12
Grate area, one boiler, square feet	66.00
Ratio H.S. to G.S.	29.2 to 1.
Steam capacity 5 inches above top of combustion chamber, cubic feet	296.5
Morison's suspension furnaces used.	
Thickness of shell plates, inches	$1\frac{1}{16}$
Thickness of top parts of heads, inch	1
Thickness of tube sheets, inch	$\frac{3}{4}$
Thickness of bottom parts of heads, inch	$\frac{3}{4}$
Closed fire room, forced draft.	

The *Chitose* will carry a heavier armament than either of the United States cruisers *Minneapolis* or *Columbia*. It will be supplied by the Japanese Government and will consist of two 8-inch quick-firing guns at the sides, ten 4.7-inch quick-firing rifles mounted in broadsides, with a secondary battery of twelve 12-pounder quick-firing rifles and six 2.5-inch Hotchkiss guns. There will be five torpedo tubes, 14 inches in diameter. This cruiser has two steel masts provided with fighting tops, in which the rapid-firing guns will be placed. She is equipped with four powerful searchlights and there are eight steering stations to provide for almost any contingency. Engines are protected by solid steel hatches.

A New Japanese Battleship.—The new battleship for the imperial Japanese Navy, the construction of which Messrs. Vickers, Sons and Maxim, Limited, are now commencing at their Naval Construction Works at Barrow-in-Furness, is to be 400 feet long between perpendiculars, 76 feet beam, with a draught of 27 feet 3 inches, this being the limit for Japanese waters, and the displacement will be 15,200 tons. The armor will extend right to

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the ram, and will vary from 9 inches to 4 inches in thickness. The barbettes will be of 14 inches to 10 inches steel, and the protective deck will be 4 inches on the slopes and 2½ inches on flat part. The engines will develop 15,000 indicated horse power, giving the ship a speed of 18 knots, when running at their normal piston speed. Belleville boilers will be used, 25 or 26 in all, and they will be as liberal in their proportions as in the case of the boilers of recently-constructed British battleships, while the working pressure will be 300 pounds at the boilers and 250 pounds at the engines. The twin engines will be of the triple-expansion type, with three cylinders, the diameters being: High pressure, 31 inches; intermediate, 50 inches, and low pressure, 82 inches, with a stroke of 48 inches. The armament will consist of four 12-inch breechloading guns, mounted in pairs in barbettes, two at the forward and two at the after end of the vessel; fourteen 6-inch quick-firing guns, ten being placed on the main deck and four on the upper deck; twenty 12-pounder quick-firers in suitable positions on the upper and main decks; a large number of machine guns, and four submerged 18-inch torpedo tubes.

Ikadsuchi.—We here give a view of a torpedo-boat destroyer, built by Messrs. Yarrow and Company, Limited, for the Imperial Navy of Japan. This vessel ran a preliminary trial on December 16 over the Maplin measured mile with remarkable results, and it may here be stated that our illustration is a reproduction of a photograph taken from a tug, when the vessel was actually traveling at over 31 knots, the exposures of the plate having been made whilst the vessel was on the mile. The *Ikadsuchi*, for that is the vessel's name, is the first of six similar craft built by Messrs. Yarrow and Company, for Japan. She is a twin-screw boat 220 feet long, and 20 feet 6 inches wide, and is propelled by two sets of four-crank triple-expansion engines, which are balanced on the Yarrow, Schlick, and Tweedy principle; this method has been adopted with considerable success by builders of larger vessels. It may be added that on the trial of the *Ikadsuchi* the running was exceedingly steady at all speeds. In each set of engines the high-pressure cylinder is 20½ inches,

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the intermediate cylinder 31½ inches, and the two low-pressure cylinders each 34 inches in diameter, the stroke being 18 inches. In accordance with the usual practice now followed by this firm, the two low-pressure cylinders are placed at the ends of the set. There are four boilers of the Yarrow straight-tube type.

On the trial made on the 16th instant, the contract load of 35 tons was carried, and the contract speed of 31 knots was more than reached during four runs on the mile, without pressing the machinery. The engines are designed to give 6,000 horse power, but it was shown by the trial that an ample margin has been allowed, and it is estimated that 7,000 indicated horse power could be reached if needed. The steam pressure on trial averaged 185 pounds per square inch. The revolutions were 410 per minute, and the draught 8 feet 6 inches. The armament will consist of one 12-pounder quick-firing gun mounted aft, and five 6-pounder guns. There are two torpedo guns on deck for 18-inch torpedoes. The coal capacity is 90 tons, which is amply sufficient to take the vessel across the Atlantic at a fair speed. The official trials of these six vessels will take place during the new year, and to judge by the trip made with the *Ikadsuchi*, the Japanese authorities need have little doubt that Messrs. Yarrow and Co. will amply fulfil the certainly onerous conditions of their contract, and more than reach the exceptional speed promised.

TORPEDO-BOAT DESTROYER FOR JAPAN.

The first of six torpedo-boat destroyers built for the Imperial Navy of Japan by Messrs. J. I. Thornycroft and Company, of Chiswick, underwent her official trial trip off the mouth of the Thames on Monday the 5th inst., making a speed of 30¼ knots in a three hours' run. This vessel is of the same type and dimensions as the 30-knot boats built by the same firm for our Navy. Messrs. Thornycroft have four of the latter vessels ready for delivery besides H. M. S. *Albatross*, which is now under trial. It will be remembered that this vessel is one of the two experimental destroyers of higher speed ordered by the Government some time ago.

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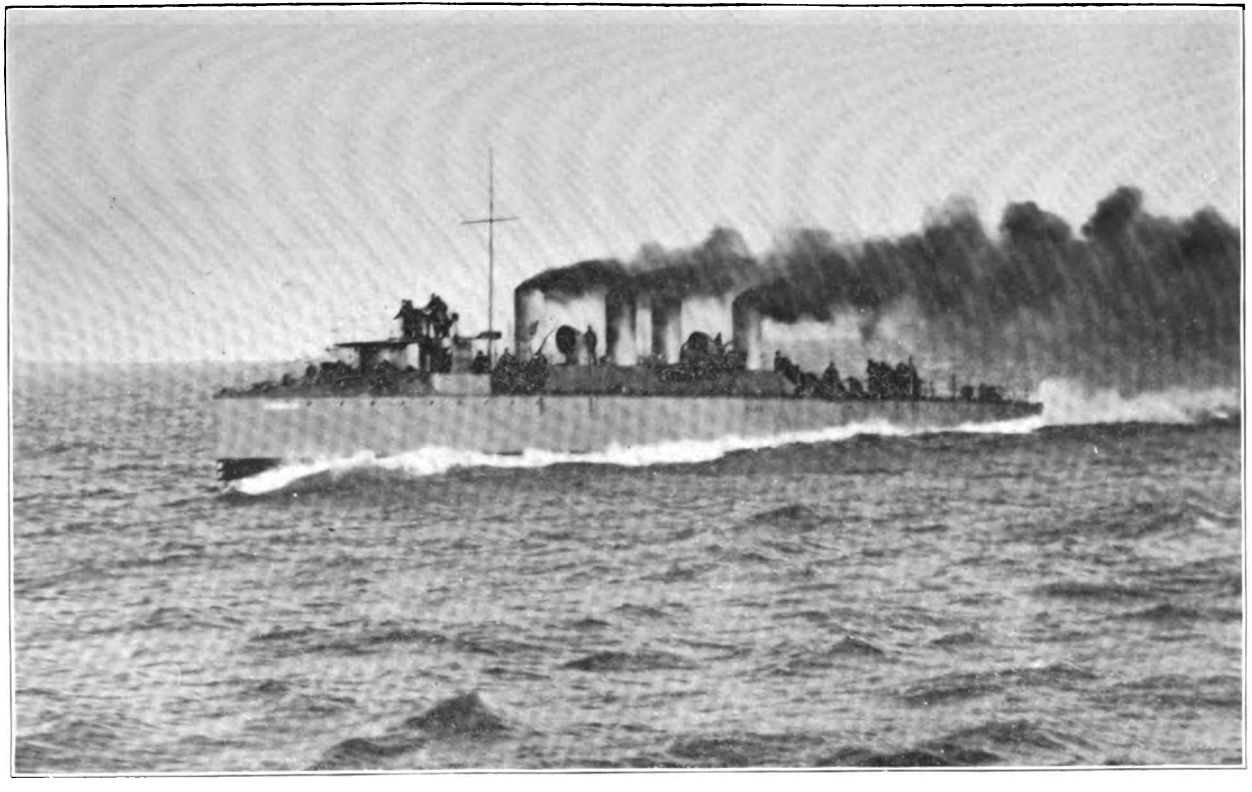

JAPANESE TORPEDO-BOAT DESTROYER "IKADSUCHI."
(STEAMING AT 31 KNOTS PER HOUR.)

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The *Murakumo*, which means "The Darkening Clouds," is 210 feet long, 19 feet 6 inches wide, and 7 feet deep, the mean draught being 5 feet 8 inches. She has twin screws, and is built of special steel of a high tenacity, being about 40 tons. The armament consists of two 18-inch torpedo tubes, five 6-pounder quick-firing guns, and one 12-pounder quick-firing gun. The latter is mounted in the stern of the vessel instead on the conning tower, as in the English boats.

The engines are of the usual balanced type adopted by Messrs. Thornycroft for these craft, having cylinders 20 inches, 29 inches and two of 30 inches in diameter, with a stroke of 18 inches, running at 400 revolutions per minute, thus giving the very high piston speed of 1,200 feet per minute.

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MERCHANT STEAMERS.

Oceanic.—The Oceanic Steam Navigation Company's splendid new vessel was successfully launched January 14, and before the end of 1899 will be on her station. Up to that time little had been known concerning her, but we are now enabled to give a few of the leading particulars of the great ship.

In the new *Oceanic* we will have a vessel of from a knot and a half to two knots less speed than the fastest vessels at present afloat. In short, her average speed will be from 20 to 21 knots, although there is a 23-knot liner building in Germany of smaller size than the *Oceanic*. She will thus be a little faster than the *Teutonic*, and the fact that she will be the largest vessel in the world, though not so fast as the *Campania*, *Lucania* or *Kaiser Wilhelm Der Grösse*, constitutes her a pioneer ship.

Every effort is being made in the new vessel to render her even more uniform in her passages than her predecessors in the fleet, one of which, the *Britannic*, earned for herself the expression, "as regular as a railway train." The *Oceanic* will be over 5,000 tons larger than any liner of her speed, and nearly 3,000 tons larger than the present largest vessel in the world. She will be twice the size of the largest battleship afloat. It is proposed ordinarily to drive her at about 20 knots, but she will be capable of 21 knots for the voyage if necessary, or about the same speed as the *St. Paul*. In stormy weather, therefore, she will be "let out," and similarly will make good any other delays on an ordinary voyage. The idea is to make her arrive at New York or Liverpool early on Wednesday mornings, having left the other side the previous Wednesday, and never to be so late as Wednesday evening or so early as Tuesday evening.

The *Oceanic* will, in external appearance, much resemble the *Teutonic*, except that her funnels will be much higher proportionately, in accordance with recent practice. They will be of

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the same size, height and distance apart as the *Campania's*, but owing to the vessel's vast size they will look much smaller, there being three masts also, instead of two, as in the case of the *Campania*. The three masts will mean greater convenience in dealing with cargo, and will also make her look more like a ship than the abnormally-funnelled and two-masted vessels now common. There will be no turtle backs, but otherwise the arrangements on deck will be very similar to those of the *Teutonic*.

Her gross tonage is 17,040, displacement 28,500 tons; length over all, 705 feet 6 inches, by 68 feet beam, by 49 feet 6 inches moulded depth. The total depth is about 68 feet, and the length between perpendiculars about 685 feet. The extreme load draught will be about 32 feet 6 inches. There will be fifteen fire-tube boilers—twelve double and three single ended—of about 1,100 tons total weight. The engines will be triple, four-cylinder, four-crank, balanced, as in the *Kaiser Wilhelm Der Grösse*, of about 28,000 indicated horse power, working with 195 pounds of steam, and driving two three-bladed propellers, 22 feet diameter, placed very close together, with an opening between them, the circumferences of the tip circles being about 9 inches apart in same plane. The cylinders are 47½, 79 and two of 93 inches diameter, by 6 feet stroke, and the crank shafting is 25 inches diameter with crank pins 26 inches diameter.

The forefoot is cut away, and the deadwood is also similarly lessened, the keel raking up aft for about 40 feet. The propeller shafts are protected by the skin plating and frames of the ship, no part of the shafting being exposed, and the stern brackets not being visible from the outside, after the method first introduced for twin-screw vessels by Mr. Pirrie in the *Teutonic* and *Majestic*. There is a very long forecastle, and the strake under the upper deck from forecastle to the poop is specially strengthened by very large round-headed rivets. This is the only part of the ship in which round-headed rivets have been used. Everything in the construction of the vessel points to extraordinary strength, the object being to minmize depreciation.

The vessel will have the largest electric-light installation fitted on shipboard. There will be twenty-two ordinary life boats. Her

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bilge keels are 18 inches deep, and she is flatter on the floor than the *Teutonic*, and she has less "tumble home." As a cruiser she will be able to steam 24,000 nautical miles at 12 knots—or round the world—without coaling. The *Teutonic*, which next to her possesses the greatest coal endurance of any vessel—war or merchant—can steam 21,600 miles at 10 knots. This means that the *Oceanic* will steam 23,400 miles in eighty-one days, and the *Teutonic* 21,600 in ninety days; in other words, in a distance of about 22,000 miles the *Oceanic* will steam 2,000 miles more than the *Teutonic* in nine days less time.

The New Steamship Deutschland.—The Germans have proved the efficiency of their shipyards by undertaking the construction of one of the hughest steamship of modern times. This new giant, which is in process of construction in the Vulcan shipyard at Stettin, will be called *Die Deutschland*, and will be if not the largest, the fastest steamer in the world. According to the Hamburg "Boersenblatt," this floating palace, which is now so well advanced that she will be launched in six months or less, has a length of 622 feet, a beam of 67 feet and a depth of 44 feet. To form a correct idea of these dimensions, let it be recalled that the *Pennsylvania*, of the Hamburg-American Line, was the largest steamship in the world at the time of her completion, having a length of 560 feet; yet the *Deutschland* exceeds her in length by 62 feet. With her bunkers and ballast tanks filled, the *Deutschland* will draw 29 feet of water. Her coal bunkers will have a capacity of 5,000 tons. She will be provided with two six-cylinder, quadruple-expansion engines, whose aggregate capacity will be 33,000 indicated horse power. It is difficult to comprehend this enormous power. The steamer *Prince Bismarck* has 16,500 horse power, and the steamers *Pennsylvania* and *Pretoria* have only 5,500 horse power each, with which they attain a speed of 13 or 14 knots. Thus the *Deutschland* will have twice the engine power of the *Prince Bismarck*, and six times that of the *Pennsylvania*. Twelve double boilers, each with eight furnaces, and four single boilers, each with four furnaces, will be provided to furnish the steam for the mighty engines, so that there will be 112 fires in all in the stoke hold. The steam pressure is to be

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210 pounds, and the contract calls for an average speed of 23 knots per hour, although it is expected that 25 knots may be attained as a record performance. Five dynamos will be used to run the electric lights. Twenty-six life-boats will be provided —eighteen of steel, two of wood, and the remaining six will be of the collapsible type.

A better idea of the size and power of the *Deutschland* may be had, perhaps, by comparing her with the *City of New York*, whose engines develop some 18,000 or 20,000 horse power, or about 60 per cent. of that developed in the *Deutschland*. "It is a very easy matter to talk of 18,000 or 20,000 horse power," says an article in the "Locomotive" for March, 1889; "but few persons, we think, realize what it means. Assuming that the engines will require 18 pounds of steam per horse power per hour, then 160 tons of feed water must be pumped into the boilers every hour, and 160 tons of steam will pass through the engines in the same time. In twenty-four hours the feed water will amount to 3,840 tons. A tank cubical measuring 52 feet on the side would hold one day's consumption; or it would fill a length of 493 feet of a canal 40 feet wide and 7 feet deep. Taking the condensing water at thirty times the feed water, it will amount for a six days' run across the Atlantic, to not less than 691,200 tons. This would fill a cubical tank 295 feet on the side—a tank into which the biggest church in New York, steeple and all, could be put and covered up. The coal consumed will be 400 tons per day. This will require, for its combustion, 8,600 tons of air, occupying a space of 220,000,000 cubic feet. It is impossible for the mind to take in the significance of these latter figures. It may help if we say that if this air were supplied to the ship through a pipe 20 feet in diameter, the air would traverse the pipe at the rate of about 5.6 miles per hour." If the figures here given are all increased by about 70 per cent., some conception may be had of the vast quantities of water and coal and air that must be handled every time the new *Deutschland* crosses the Atlantic.—"Marine Record."

Great Lakes Freight Steamer C. A. Black.—The Detroit steamer *Clarence A. Black* is regarded as one of the most econ-

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omical freight carriers in this country. This vessel, built by the Cleveland Shipbuilding Company, and fitted with the Howden system of hot draft, through arrangement with the Dry Dock Engine Works of Detroit, is credited in two elaborate reports of tests with having shown a fuel consumption of a little less than 1½ pounds of coal per indicated horse power per hour. The *Black* is a vessel of the ordinary coarse-freight type in general use on the great lakes, and is of 6,800 net tons capacity. She is 414 feet over all, 50 feet beam, 28 feet depth. Her load of 6,800 net tons is carried on about 17 feet draught. Engines are of triple-expansion type, with cylinders of 22, 35 and 58 inches diameter and 40 inches stroke; air pump, 32 inches diameter and 14 inches stroke. She has two Scotch boilers of 13 feet 2 inches diameter and 12 feet length over all, allowed 165 pounds working pressure; four furnaces, 48 inches inside diameter, with grates of 5 feet 6 inches = 88 square feet; total heating surface, 4,292 square feet; propeller, sectional, four bladed, 13 feet 6 inches diameter and 14 feet pitch.

Particulars of a trial of this vessel, showing a consumption of only 1.46 pounds of coal per I.H.P. per hour, are as follows: Steam pressure, 165 pounds; vacuum, 22 inches; average revolutions, 87.7; indicated horse power, H.P. cylinder, 482.3; I.P. cylinder, 538.5; L.P. cylinder, 505.8; total average, 1,526.6; ref. M.E.P. to L.P. cylinder, 32.7; ratio of horse power to grate surface, 17.3; ratio of heating surface to horse power, 2.8; duration of test, 6 hours 2 minutes; total coal burned, 13,440 pounds; coal per hour, 2,228 pounds; coal per hour per I.H.P., 1.46 pounds; coal per hour per square foot of grate surface, 25.32; air pressure at fan, 1⅛ pounds; temperature at hot well, 139 degrees; temperature of feed water after leaving heater, 175 degrees; speed of vessel, 12.23 miles; speed of propeller, 13.95 miles; slip of propeller, 23.3 per cent.

Ocean Records in 1898.—The honors of the past year for fast steaming across the Atlantic again go to the North German Lloyd steamer *Kaiser Wilhelm der Grosse*, which has improved upon her record of November, 1897, and on the Southampton-New York route is unapproached. She has also contrived to beat

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the *Lucania's* best for a day's run, and may, therefore, be regarded as the fastest merchant vessel afloat. It can, of course, be no particular gratification to us, says a correspondent in the "Times," to contemplate this situation and to be compelled to admit that a vessel of exclusively German construction has beaten the best that we have hitherto produced. There is consolation, however, in the prospect that the *Kaiser Wilhelm der Grosse* will not retain the honor long. The new *Oceanic* of the White Star Line is to be launched on January 14 at Belfast. Her length is 704 feet over all, or 13 feet longer than was the *Great Eastern*, and her gross tonnage is over 17,000. In some respects she marks a great departure in steamships, and though her owners strongly depreciate all ambition to produce a vessel which shall be remarkable first and last for steaming power, it is well recognized that this point has been kept well to the front, and all we have been told of her fully justifies the expectation that she will prove to be the newest sovereign of the seas. Meanwhile, we may return to the *Kaiser Wilhelm der Grosse*, whose performances during the current year are shown in the following tables, compiled from abstracts of the ship's logs:

WESTWARD.

Date.	Passage.			Distance.	Average. speed.
	d.	*h.*	*m.*	*Knots.*	*Knots.*
March	5	23	37	3,100	21.59
March 30	5	20	0	3,120	22.29
April 27	6	3	57	3,115	21.06
May 25	5	21	48	3,130	22.07
June 24	6	2	13	3,123	21.36
August 3	6	2	10	3,050	20.87
September 28	6	2	38	3,052	20.81
November 2	6	5	27	3,050	20.41
EASTWARD.					
March 16	5	19	30	3,027	21.77
April 12	5	23	2	3,035	21.22
May 10	5	16	48	3,035	22.19
June 7	6	19	20	3,190	19.53
July 5	5	19	45	3,146	22.51
August 16	5	23	30	3,075	21.43
October 11	6	6	27	3,080	20.47
November 15	5	20	20	3,077	21.92

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It may be remembered that the best of the three outward runs of the *Kaiser Wilhelm* in 1897, was the first, when she steamed to New York in 5 days 22 hours 30 minutes, giving an average speed of 21.39 knots. The best of the three eastbound runs, excluding the first, which was to Plymouth instead of to Southampton, was the 5 days 17 hours 8 minutes of November, an average of 22.35 knots. A glance at the table will show that during the present year both these times have been reduced. The record day's run outwards of the *Lucania* is 562 knots and homewards, 526 knots; while the *Campania's* best stands at 553 knots outwards and 528 knots homewards. These achievements have not been surpassed during 1898 by either of the Cunard vessels. Appended are details of the best passages of the leading vessels of the two lines:

CUNARD LINE.

—	Out.			Average speed.	Home.			Average speed.
	d	*h.*	*m.*	*Knots.*	*d.*	*h.*	*m.*	*Knots.*
Lucania	5	10	37	21.30	5	11	54	21.99
Campania	5	11	13	21.21	5	13	46	20.96
Etruria	5	20	55	19.74	6	2	37	19.13
Umbria	6	3	32	18.88	6	6	46	18.59
WHITE STAR LINE.								
Majestic	6	0	5	19.65	6	2	57	19.37
Teutonic	5	23	42	19.90	5	23	44	19.60
Germanic	7	3	38	16.61	6	23	14	16.77

Apart from the bringing of Egypt to within four days of London, the Peninsular and Oriental Company has to report no special passages this past year. The two express steamers *Isis* and *Osiris*, each of 1,728 tons gross register and of 6,500 horse power, are now at work in the mail service between Brindisi and Port Said. They perform the voyage in about 48 to 50 hours, and enable those passengers who leave London at 9 P. M., on Fridays by the "P. and O. Brindisi Express" to reach Port Said on the following Tuesday night. The fastest trip yet made was by the *Osiris* in 47 hours, which represents an average speed of 20 knots —probably the greatest speed ever maintained for so long a period

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by any merchant vessel of corresponding size. These express boats transfer the mails at Port Said to the large passenger steamers, which now make Marseilles their regular port of call instead of Brindisi. The old P. and O. records have to be again carried forward, as it were, for the current year, and it may be of interest if they are repeated here: Mails to Bombay in 12 days 10¾ hours by the *Caledonia*; from Bombay in 12 days 2 hours by the same vessel; to Hong Kong in 24 days by the *Australia* and the *Oriental*; to Western Australia in 23 days 11½ hours by the *Himalaya*, and to Melbourne 34 days 20 hours by the *Victoria*.

On the Cape Town route good, steady work has been accomplished by the steamers of the two leading lines. The fastest passages of the Union Company's vessels between Southampton and Cape Town, and *vice versa*, are shown in the following table:

Steamer.	Outward voyage.		Homeward voyage.	
	d.	*h.*	*d.*	*h.*
Briton	16	0	15	6
Mexican	17	0	16	19
Moor	17	12	16	9
Norman	16	5	15	9
Scot	16	4	15	8

The Castle Line records are as follows:

Steamer.	Outward voyage.			Homeward voyage.		
	d.	*h.*	*m.*	*d.*	*h.*	*m.*
Dunottar Castle	15	17	50	15	4	30
Dunvegan Castle	16	0	6	15	9	30
Tantallon Castle	16	5	54	15	14	49
Carisbrook Castle	16	11	0	15	1	11

It will be seen that the *Dunottar Castle* is the best steamer of the year on the outward and the *Carisboook Castle* on the homeward run.

Turkistan.—This steel screw steamer left the port of the Hartle pools for its trial trip on December 5. The vessel has been built by Messrs. Wm. Gray and Co., Limited, for Messrs. Frank

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C. Strick and Co., Limited, of Swansea and London, the principal dimensions being: Length over all, 362 feet; extreme breadth 45 feet; depth, 25 feet 8 inches, and is of the spar-deck type, with poop, bridge and forcastle. The machinery has been constructed at the Central Marine Engine Works of Messrs. Wm. Gray and Co., Limited, and is of the triple-expansion type, with cylinders 28 inches, 43½ inches and 72 inches in diameter, and a piston stroke of 48 inches. The boilers are two in number, and are fitted with Messrs. Jas. Howden and Co.'s system of forced draft. A speed of 15 knots was easily maintained, the engines developing over 2,500 H.P., and the boilers keeping perfectly tight and furnishing a plentiful supply of steam.

Noraumore.—This turret-deck steamer, built by Messrs. Wm. Doxford & Sons, Ltd., Sunderland, to the order of the Belgian Maritime Trading Company, Antwerp, proceeded on its trial trip on December 19th. The principal dimensions are: Length, 420 feet; breadth, 50 feet; depth, 32 feet 6 inches. A speed of twelve knots was attained. Both hull and machinery have been constructed to the highest class of the British corporation.

Ultonia.—This screw steamer, which has been built for the Cunard Steamship Co., Ltd., by Messrs. C. S. Swan and Hunter, Ltd., was taken out to sea on October 28, for the trial trip. This is the largest steamer that has been built on the Northeast coast, or, in fact, in England, and is of the following leading dimensions: Length over all, 513 feet; breadth, extreme, 57 feet 4 inches; and depth, molded, 37 feet. Above the upper deck is a shelter deck extending the whole length of the vessel, and which is fitted up for carrying cattle, with fittings of the latest type. At the fore end of the vessel on this deck, accommodation is provided for the crew and firemen, and at the other end for a large number of cattlemen. Above the shelter deck is a long bridge extending out to the full width of the vessel, and which, like the shelter deck, is fitted up for the carriage of cattle, of which, on the two decks, she will carry 800 head. Above the bridge, in a large house round the engine and boiler casings, are situated the saloon and rooms for officers, petty officers, engineers, foremen cattlemen, etc. Over this house is a house

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containing the master's room, chart room, and wheel house, and over all the navigating bridge. Three large refrigerating engines, made by the Liverpool Refrigeration Co., have been fitted at the forward end of the bridge, the whole of the lower 'tween deck forward being insulated for the carriage of chilled beef, bacon, etc. The engines have been built by Sir Christopher Furness, Westgarth & Co., Ltd., Middlesbrough, and drive twin screws. Each engine is of the triple-expansion type, and has cylinders 23½ inches, 38½ inches and 66 inches diameter, with a stroke of 48 inches, steam being supplied by five large single-ended boilers working at a pressure of 200 pounds per square inch, and fitted with Howden's system of forced draft.

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YACHTS.

The Steam Yacht Ellide.—The steam yacht *Ellide* designed by C. D. Mosher for E. Burgess Warren, of Philadelphia, has shown on trial such an unprecedented speed that a description of the boat and machinery and of her trials should be of great interest to all who are concerned with the advance of marine construction, and especially with the development of the highest attainable speeds on the minimum size and weight.

The *Ellide* is 80 feet long, 8 feet 4 inches maximum beam, and, aside from the propeller, has a draught of about 2 feet. The normal displacement is about 13 tons. The boat is of composite construction, and is subdivided by five steel bulkheads into six water-tight compartments. The planking is of double-skin mahogany, and all the fastenings are Tobin bronze bolts.

There is one Mosher patent quadruple-expansion engine with cylinders 9 inches, 13 inches, 18 inches and 24 inches diameter by 10 inches stroke. All cylinders are fitted with piston valves, and have relief valves on both upper and lower heads. The steam chests are fitted with automatic by-pass valves. None of the cylinders have steam jackets, but all are properly lagged with magnesia and encased in polished brass.

The valves are worked by an independent valve crank shaft parallel to the main shaft, and so geared to it by double helical gears as to make an equal number of revolutions with the main shaft. Reversing is accomplished in the usual way by a spiral sleeve actuated by a reverse lever at the forward end of the engine.

All the material used in the construction of the engine is of the highest class. The main parts of the engine are of steel forgings, oil tempered and bored out hollow, and all the usual fittings are supplied in accordance with advanced engineering practice.

The propeller is 40 inches in diameter, and of about 60 inches mean pitch.

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In addition to the main propelling engine there is an inboard surface condenser, and six especially-designed auxiliaries, including feed pumps, air pumps, circulating pump, bilge pump and blower. The latter supplies air to the furnaces on the closed ash pit system.

The boiler is of the Mosher water-tube type, encased in polished brass. It consists of two steam drums placed over two water drums and connected together by a number of solid-drawn steel tubes, so arranged that the gases pass twice the length of the boiler at right angles to the tubes before entering the stack, thus a high proportion of the heat liberated is absorbed, giving to the boiler a high efficiency. Each side of the boiler is practically independent, although the furnace is common to both.

The boiler has 1,203 square feet of heating surface and 30 square feet of grate surface, and is similar to those now in use in nine of the torpedo-boats of the U. S. Navy.

The trials were carried out over the statute-mile course of 5,280 feet, recently laid off by the U. S. Coast Survey steamer *A. D. Bache*, on a straight line, off Irvington-on-Hudson. The ends of the course were marked by range poles on the river bank at right angles to the course. On each run the speed of the boat was adjusted by the throttle valve, and the steam pressure maintained as nearly uniform as possible. The judges in the forward cockpit took the time with stop watches, and by a single stroke of the bell at the beginning of the mile, signaled the engine room, where indicator cards were taken, and the steam pressure and revolutions were recorded. On each of the runs over the course indicator cards were taken from each of the cylinders, and the revolutions were taken by a special speed indicator connected to the shaft of the engine. The indicators used were specially designed by Mr. Mosher for extreme high speeds, and were made under his direction by the Crosby Steam Gage Company.

Owing to the form of the boat, the entrance lines become finer and finer as the bow continues to rise out of water, while, due to the breadth and form at the stern, there is no settling or squatting at any speed. It further follows that as the bow rises the run or

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buttock lines continue to become more nearly horizontal, so that at the highest speeds the after body is in large part simply sliding along nearly parallel to the surface of the water.

The highest number of revolutions on any one run was 822 per minute, but at this speed indicator cards were not secured for all cylinders.

Professor W. C. Durand, in an interesting paper in "Marine Engineering" of December, discussed the results, and it is from that article these extracts are made.

Trial Speeds Obtained.

Revolutions per minute.	Total I.H.P.	Speed, miles.
285	58.19	12.7
418	179.62	19.05
560	386.	27.3
620	542.56	31.2
748	788.93	37.
822	910.	*40.

The I.H.P. for the last run was obtained by extending the power-speed curve to the vertical ordinate through the revolution curve at 822 revolutions, checking it also by extension of revolution-speed curve.

The New Steam Yacht "Aphrodite."—The new steel ocean-cruising steam yacht *Aphrodite* was successfully launched from the shipyard of the Bath Iron Works, at Bath, Maine, on Thursday of last week. The vessel is being constructed for Col. Oliver H. Payne, of New York, who will use her for lengthy voyages. In fact, when Colonel Payne gave orders for the design of the new steam yacht, his instructions were to the effect that the vessel should be staunch enough to voyage around the world and capable of spending many days at sea. The designs were made by Charles R. Hanscomb, of the Bath Iron Works, and the entire vessel, down to the smallest detail, will be the product of this well known shipbuilding concern.

The *Aphrodite* will have the distinction of being the largest,

*40 miles corresponding to 34.73 knots.

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most luxuriously appointed and speediest sea-going steam yacht ever constructed in this country. No expense is being spared in making this vessel just what the specifications insist upon, viz: the finest pleasure craft of her type afloat.

The hull of the new craft is 306 feet over all, or 263 feet between perpendiculars; 35½ feet beam, and she will draw when loaded 16 feet of water. The steel hull of the vessel is constructed in a remarkably strong and rigid manner, and her scantlings are in excess of the requirements of the rules of the American Shipmasters' Association. The yacht has a flat keel instead of the usual side-bar keel. She has moderate deadrise, an easy bilge with graceful curving sides, and the usual "tumble home." The bow lines flare above the load-water line so as to make the vessel more comfortable in a head sea. She is fitted with bilge keels or rolling chocks 24 inches deep and 140 feet long.

No permanent ballast will be necessary to insure sufficient initial stability, but four large water-ballast tanks are fitted, two forward and two aft of the machinery space, so that the displacement can be increased, and the trim, when light, regulated at will. The hull of the vessel is divided into fifteen water-tight compartments. There are no less than nine athwartship steel bulkheads, and no doors are cut in any of them except where absolutely necessary.

There are many innovations in the construction of this interesting vessel. The main deck is plated with heavy steel throughout the entire length. A top gallant forecastle deck is fitted forward with full head room between it and the main deck. The large deck house, 160 feet in length, is a steel structure of great strength and rigidity, but this metal work will soon be concealed by handsome paneled mahogany. Large round, vertical, sliding air ports are fitted in this house. These are more efficient on the ocean-going vessel, and they also tend to give a much more shipshape appearance than the rectangular windows. There is a clear deck space of about 7 feet between the rail and the deck house on each side.

It is apparently the desire of the owner to secure ample deck space and freedom at sea rather than large rooms in which to

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entertain. The *Aphrodite* has a rounding stern with a medium overhang, and the stern lines of the vessel are such as warrant good behavior when running before a heavy sea. The interior arrangement of the vessel will be of the most superb character, the woodwork being handsomely carved, most of which is now in the joiner shop at the Bath Iron Works ready to go on board. The yacht is to be fitted with all the modern appliances, electric lights, two search lights, storage battery, steam windlass, etc., etc.

The engines of the *Aphrodite* will be the largest ever placed on board of a private-owned pleasure craft in this country. The cylinders are 28, 43 and 70 inches in diameter respectively, and the stroke is 38 inches. There are four massive single-ended boilers all ready to be lowered into the vessel. At natural draft these boilers will supply steam for 3,200 indicated horse power. There is no yacht afloat to-day that is fitted with machinery capable of developing this power at natural draft. The speed of the *Aphrodite* under steam alone, without forcing, will be at least fifteen knots per hour, and this she will be able to maintain on a long run, owing to her great boiler power and large coal capacity. Under forced draft she will make over seventeen knots per hour.

She is to be bark rigged, two-thirds full sail power, and will spread in all about 17,000 square feet of canvas. These sails will give steadiness in a sea-way, and in an emergency will enable her to make fair speed under canvas alone.

The *Aphrodite* has been constructed in a new, substantial steel ship house 316 feet long and 50 feet wide. Pneumatic tools have been used in her construction, and owing to the Bath Iron Works having most excellent facilities for this high class of work, they have turned out in a very short time a hull that for strength, beauty and fine workmanship is excelled by none at present afloat.

Sixteen Large Steam Yachts are in process of construction or contracted for in American shipyards, most of which are to replace yachts that were taken by the Government for naval use during the war. The largest of the lot are the new *Corsair*, now being engined and completed by the W. & A. Fletcher Co., Hoboken, for Commodore J. Pierpont Morgan, of the New York Yacht Club, which is 304 feet long over all, and the *Aphrodite*,

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now being built at Bath for O. H. Payne, described above. Two of the others, however, considerably exceed 200 feet in length, the ones for Mr. Widener and Mr. J. P. Duncan, and all the remainder are much over 100 feet long—a stanch, able, sea-going fleet. There is no room for doubt that the presence of considerable of this work in American shipyards is due to the existence of the Payne yacht law, which was framed and fostered by the "Marine Journal," prohibiting foreign-built yachts from enjoying the privileges of the American flag. And without doubt orders for many more will follow.—"The Marine Journal."

Chil Howee.—The following is a description of the propelling machinery of the steam yacht *Chil Howee*, belonging to Mr. Wm. H. Evans, of Baltimore, Md.

The yacht is 126 feet long over all, 100 feet on the water line, 16 feet beam, 10½ feet deep, and 6½ feet draught. The hull is of wood, and was built by Messrs. Jos. Thomas & Son, Baltimore, Md., and the machinery by Messrs. Morton, Reed & Co., Baltimore, Md. The boilers and engines were designed by Mr. Samuel J. Williams.

The machinery space in the yacht is 22 feet 6 inches long. Three feet of this space forward of the boilers was reserved for coal bunkers. This with the two side bunkers will carry seventeen tons of coal.

There are two boilers, of the pipe or coil type, each 8 feet ½ inch long, 4 feet 4 inches wide and 7 feet high. Each boiler contains a little over 725 square feet of heating surface, and 21.6 square feet of grate surface, the furnaces being 6 feet 9 inches long and 3 feet 2 inches wide. The upper water drum is 20 inches inside diameter, 8 feet long, made of ½-inch steel, with flanged heads of ½-inch steel.

The feed-water heater consists of two narrow, box-shaped manifolds with a series of inverted U-shaped coils of pipe screwed into them. The feed water enters at one end of one of the manifolds, slowly passing up and then down through the coils into the next manifold, and from a point in that manifold, near the top, a pipe leads to one of the down-flows of the boiler, discharging the feed water at that point into the boiler.

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The superheater coils are in two parts, taking steam from each end of the steam drum, then, after traversing back and forth, the steam enters a drum from which it is then taken by the main connection to the engine. The same construction applies to the other boiler.

The boilers are entirely under the deck, an iron plate flush with the deck, covering the boiler space.

There are twelve separate fresh-water tanks, six forward and six aft, under the floors, with a capacity for about 1,200 gallons fresh water.

The engines are triple expansion, with cylinders 9 inches, 14 inches, and 24 inches by 14 inches stroke. The valves are all piston valves, working in removable cages. All the valves have packing rings. The cylinders are three separate castings, placed as close together as possible, and the valve chests are on the side, the valves being operated by the Marshall valve gear. The cylinders are supported by seven straight steel columns. The base plate is of cast iron, well ribbed on the under side.

As the Marshall valve gear is used, there is but one eccentric to each engine proper, and the three eccentrics were made in the shaft forging, thus making the shaft with its three cranks and three eccentrics one solid forging. The high-pressure crank pin and bearings are 4½ inches in diameter, and the intermediate and low-pressure crank pins and bearings are 4¾ inches in diameter. The main shaft journals are 8 inches and 10 inches long.

The dimensions of the propeller wheel are as follows:

Diameter of wheel, feet,	5.5
Pitch of wheel (true screw), feet,	8.5
Number of blades,	4
Diameter of hub, inches,	9
Length of hub, inches,	11.75
Helicoidal area, square feet,	12.97
Disk area, square feet,	23.75
Greatest width of blade (21 inches from axis), feet,	1.5
Helicoidal area divided by disk area,	.546

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The thrust and propeller shaft are 4½ inches diameter, of steel, the total length being 38 feet 5 inches. The propeller is 5 feet 6 inches diameter, 8 feet 6 inches pitch, made by H. G. Trout, Buffalo, N. Y.

The surface condenser is of the Wheeler type, with 350 square feet of cooling surface, with Deane (of Holyoke) air and circulating pumps.

The boilers are fed by a Deane duplex high-pressure pump, and a Metropolitan double-tube injector. The pump and the injector are independent, and each can take its feed water from either the filter box, tanks, or from overboard. There is also provided a Deane duplex pump for pumping out the bilge, for fire purposes, and for washing decks.

As to the performance of the plant, it was found that everything worked satisfactorily, except that the engine could not be turned up to the designed speed. This was attributed to the size of the wheel, which is rather large for the engine. The highest number of revolutions made was 200. (The engineer has since stated that he has made 225 revolutions.)

At these speeds the engine turns up very smooth and free from vibration.

No accurate tests were made, but in twenty minutes from the time of lighting fires 200 pounds of steam was on the boiler, and as the engines have not been run up to their designed speed (which is 300 revolutions per minute), the boilers have not been given a severe test.

The owner reports that he ran from Cape Charles to Baltimore in 13 hours using *one* boiler, making steam easily, and the engine turning from 160 to 180 revolutions per minute.

Natural draft is used altogether, the height of stack (26 feet from the grate) giving excellent draft.

The steam is slightly superheated. The boilers show no tendency to foam or to lift the water. The circulation is very active, and all parts of the boiler keep an even temperature.

As the yacht was finished somewhat late in the season, she was taken without making any trial trips, except just enough to

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see that the machinery was in order and for setting the valves.

At about 12 knots the following data were obtained:

Indicated H.P., H.P. cylinder,	99.33
Indicated H.P., I.P. cylinder,	94.75
Indicated H.P., L.P. cyiinder,	65.5
Total horse power,	259.58
Boiler pressure, by gage, pounds,	205.
First receiver, by gage, pounds,	62.5
Second receiver (gage out of order).	
Vacuum, inches,	24.
Revolutions of engine,	185.
Piston speed, feet per minute,	431.6
Diameter of piston rods, inches,	1.75

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ASSOCIATION NOTES.

ANNUAL MEETING.

The eleventh annual meeting of the Society was held in the office of the Engineer-in-Chief, on the evening of the 10th of January. The meeting was of a purely business character, responses to the request in the first Association note in the November JOURNAL failing to indicate the probability of securing such papers for reading as would guarantee the desirable interest to a general meeting, if called.

The meeting was called to order at 8·35 P. M., a business quorum being present.

As no award had been made for prize essay submitted during 1898, it was so reported.

The annual report of the Secretary-Treasurer was then read, as follows:

GENTLEMEN: In accordance with the requirements of Section 14 of the By-Laws of the Society, I herewith submit the annual statement of receipts and expenditures for the twelve months ending January 7, 1899.

RECEIPTS.

Balance on hand, January 7, 1898	$5,198.59
Annual dues	1,980.20
Subscriptions, sales of JOURNALS and reprints	571.98
Advertisements	833.78
Sale of general index	8.75
Sale of society buttons	12.60
Receipts for banquet assessments, 1898	168.00
Interest on deposit	83.42
Portion of salary returned	8.50
	$8,865.82

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EXPENDITURES.

Banquet, 1898	$181.65
Printing JOURNAL and reprints	2,980.50
Printing of Index for 1897; circulars, etc	77.27
Illustrations	340.55
Salary Secretary-Treasurer	900.00
Cost of society buttons	50.50
Medal for prize essay 1897 and die for same	100.00
Stationery, postage and incidentals	107.11
Purchase of back numbers of JOURNAL	53.50
	$4,791.08
Balance on hand this date, January 7, 1899	$4,074.74
	$8,865.82

A. B. WILLITS, *Secretary-Treasurer.*

The Secretary-Treasurer in calling attention to the decrease in balance on hand, stated that it was the policy of the former Secretary-Treasurer, under whose guidance these affairs were administered up to October 1 of the year in account, to purposely reduce the growing balance by giving the Society a better and larger JOURNAL. This has proved very acceptable to the Society, as there is no good reason for retaining any more than a liberal working balance on hand. It is the purpose to continue the policy of devoting the increase of income to additions to the JOURNAL.

The accounts of the Secretary-Treasurer were duly audited later and found correct.

The work of tallying the votes for the Officers for the new year was then proceeded with, and resulted in the election of the following Officers:

President, Chief Engineer Harrie Webster, U. S. Navy;

Secretary-Treasurer, Chief Engineer A. B. Willits, U. S. Navy;

Council.—Passed Assistant Engineer C. A. E. King, U. S. Navy; Passed Assistant Engineer W. W. White, U. S. Navy; Passed Assistant Engineer Emil Theiss, U. S. Navy.

There were 140 votes received by mail for the election. These were opened at this time and counted by a committee appointed for the purpose.

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There was no motion made to amend the By-Laws, but the following amendment to the article governing the prize essay was adopted by unanimous vote of the members present.

"The offer by the Society governing the prize essay shall read hereafter as follows:

"The Society offers to the writer of the best original article on any engineering subject, that shall be contributed to and published in the JOURNAL during any one year, a prize of a gold medal, life membership in the Society, and a money prize of $75. The article may be contributed at any time during the year prior to November 1st, and articles not deemed by the Council to be of sufficient value to publish will be returned to the writer. Articles need not be marked as competitive, as the decision as to the best article published is to be obtained by mail slip, in the same manner and at the same time votes are obtained for election of officers (Sec. 23 of the By-Laws), and the award made at the annual meeting.

"A second prize for the second best original article contributed and published, as in the case of first-prize article, shall be $25 cash, and life membership in the Society. Decision to be obtained in the same way as above."

A vote of thanks was tendered to the President and Secretary-Treasurers, for the efficient manner in which they had conducted the work of the Society during the year.

The meeting adjourned at 9·57 P. M.

PERSONAL.

It will be no "news" to the readers of the JOURNAL to read here of the step from naval to civil life that Chief Engineer W. M. McFarland, U. S. N., our late Secretary-Treasurer, has recently taken. Through his professional and personal popularity there have been notices of this event published in most the leading technical periodicals, as well as local papers, uniformly accompanied by just such expressions of appreciation and laudation as his closer professional friends know he deserves. It is for the Navy and this Society of Naval Engineers to couple regret with their praise and congratulations, for while there is every reason to

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deplore the loss of such a man to the Engineering branch of the service, the excellence of the outlook in the new field of Mr. McFarland's labor is such as to compel hearty congratulations also. He is Assistant Manager of the Westinghouse Electric and Manufacturing Company, of Pittsburg, Pa., an additional light to their establishment of no uncertain power and brilliancy.

BACK NUMBERS OF THE JOURNAL.

Frequent requests are received for particular numbers of back volumes of the JOURNAL, and as the stock in hand has become greatly reduced and broken, it is requested that those having incomplete sets and not desiring to retain them, will forward a list of the single numbers they are willing to dispose of, that opportunity may be given to others for completing their sets.

Occasionally it is possible to secure a complete set of the JOURNAL to date, and should any new member or associate desire to purchase one, the Secretary-Treasurer will be glad to extend any information he has, in reply to inquiry, in order to further the interests of those who wish to preserve these valuable and "out of print" books.

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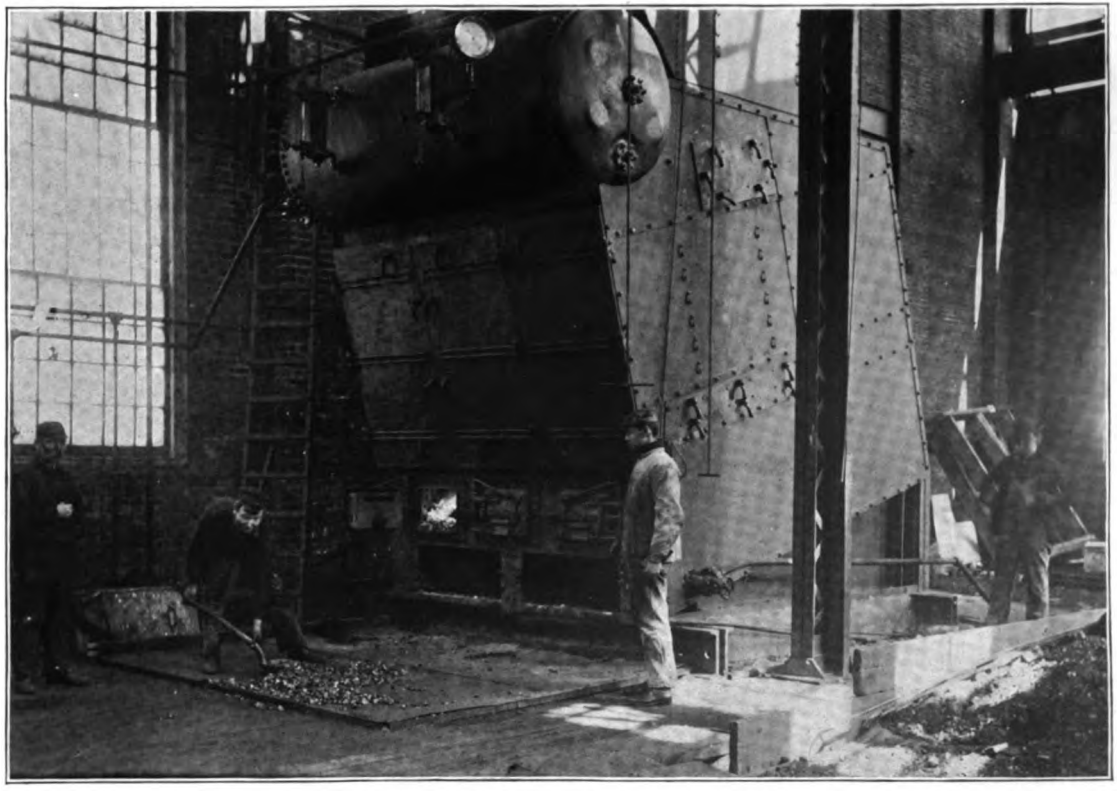

ONE OF THE "ALERT'S" BOILERS UNDER TEST AT ELIZABETHPORT.

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JOURNAL

OF THE

AMERICAN SOCIETY OF NAVAL ENGINEERS.

VOL. XI. MAY, 1899. No. 2.

The Society as a body is not responsible for statements made by individual members.

COUNCIL OF THE SOCIETY
(Under whose supervision this number is published)
Chief Engineer H. WEBSTER, U. S. Navy.
Chief Engineer A. B. WILLITS, U. S. N. Passed Ass't Eng'r W. W. WHITE, U. S. N.
Passed Ass't Eng'r C. A. E. KING, U. S. N. Passed Ass't Eng'r E. THEISS, U. S. N.
Chief Engineer A. B. WILLITS, U. S. N., *Editor.*

TEST OF A BABCOCK & WILCOX BOILER BUILT FOR THE *ALERT.*

Prior to the shipment of the two newly-constructed Babcock & Wilcox boilers to Mare Island, Cal., for installation in the *Alert*, the Engineer-in-Chief decided to supervise a series of tests in order to get, as far as possible, accurate data of performance of this type of boiler, and also to note the effect of the air-heating device which, while not a part of the *Alert* outfit, is installed in the *Atlanta*, in connection with the Babcock & Wilcox boilers there. The change in arrangement of baffles in the *Alert* boiler indicated an increased efficiency over former arrangements in the marine type and made the tests more desirable.

Chief Engineer McElroy, U. S. Navy, under whose inspection these boilers were built, and Passed Assistant Engineers W. W. White and Emil Theiss, U. S. Navy, from the Bureau, were detailed for this duty.

DESCRIPTION OF BOILER.

The construction of the marine type of the Babcock & Wilcox boiler is so well known that it will be unnecessary to enter

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into a detailed description. It will be sufficient to give the general dimensions of the boilers as constructed for the *Alert*, and to point out wherein they differ from others heretofore built for vessels of the United States Navy.

The *Alert* will have two of these boilers, placed side by side in the ship, with a passageway between them, facing an athwartship fire room.

The dimensions over all of the boilers are:

Length at bottom of ash pit, 11 feet 1 inch; distance from boiler front to perpendicular from center of drum, 19⅛ inches.

Length at top from back end to center of drum, 10 feet 5⅝ inches.

Width of boiler, 8 feet 9 inches.

Height from bottom of ash pit to center of drum, 10 feet 8½ inches.

The steam drum is 42 inches inside diameter and ½ inch thick. The heads are $\frac{9}{16}$ inch thick, one of them having an 11 by 15-inch manhole.

There are twelve sinuous headers at front and back, parallel sided, inclined 15 degrees to the vertical. The tubes are inclined 15 degrees to the horizontal and rise to the rear. The general thickness of headers, corner, cross and side boxes is ½ inch. Each pair of front and back headers is connected by a single 4-inch tube next the furnace, and by seven groups, four tubes in each group, of 2-inch tubes. Access is had to the 4-inch tubes both at front and back through the usual oval handholes. At the back ends similar handholes give access to each of the groups of 2-inch tubes. At the front ends, however, a 2-inch screw plug is fitted over each 2-inch tube. This is a change from the *Atlanta* type, and is necessitated by the wider spacing of the 2-inch tubes. The front headers are connected at the top by 4-inch nipples, 12½ inches long, to the drum, and at the bottom by short nipples of the same diameter to a cross box, which is in turn connected by 4-inch nipples to the front corner boxes. The back headers are connected by nipples to a cross box at top, from which fourteen 4-inch tubes lead to the

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center of the steam drum, namely, one tube for each of the twelve sinuous back headers and one for each of the back corner boxes.

The four corner boxes are square in cross section. Each of these boxes is made in two parts, connected by means of a 4-inch nipple and a joint, made male and female, held together moreover by a strap, $\frac{5}{8}$ inch think, secured to each part by three $\frac{7}{8}$-inch tap bolts. All the corner boxes extend to the channel-shaped bearer at bottom, to which they are secured by a 2-inch stud, which stud is forged solid with the plate, closing the boxes at their lower end, into which it is welded. The front boxes connect at top through 4-inch nipples with the steam drum. At the level of the top of the furnace-door opening they are joined by the front cross box already referred to. The back corner boxes connect at top with the cross box referred to above, which in turn communicates through 4-inch tubes with the steam drum, as described.

The pairs of front and back corner boxes are connected at their lower ends by four side boxes of square section, connected to the corner boxes by 4-inch nipples. The side boxes form the furnace sides, extending above the level of the fuel. Next above the side boxes are fitted three 4-inch tubes, expanded into the corner boxes. The topmost one of these tubes is as nearly as possible on a level with the tier of 4-inch tubes connecting the sinuous headers. Above the 4-inch tubes are arranged seven groups of 2-inch tubes, each group consisting of two tubes. Access is had to the back of all the tubes and the side boxes by means of the usual handholes. Handholes also serve to give access to the side boxes and the 4-inch tubes at the front ends. Opposite the 2-inch tubes at front ends 2-inch screwed plugs are fitted.

The water circulation proceeds in the usual way. Modifications made in the internal arrangements have produced a change in the method of circulating the products of combustion, however, making these boilers more nearly like the land type of boilers built by this firm. The furnace is inclosed at the sides by the side boxes; at the back by a slanting solid wall of fire brick, clothed on the outside with magnesia, lined on the inside with

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asbestos board, and on the outside with a No. 16 B.W.G. casing plate. The furnace front is formed by the cross box and by fire brick set between the doors.

The row of 4-inch tubes immediately above the furnace and the first row of 2-inch next above are spaced 10½ inches apart, center to center, leaving a space the full width of the boiler. The 4-inch tubes, for a length of 5 feet 6 inches from their front ends, are covered with fire brick, fitted to the shape of the tubes, forming a closed furnace at this part. At this point the space beween the 4-inch and the 2-inch tubes is closed by means of an asbestos-lined plate baffle, stiffened on the front by a T and protected on the back by a wall of fire brick and fire clay. The sections of baffles in each tier are in two parts. The flames pass over the top of the baffle just described and then pass downward between this baffle and a second one, similarly built up, extending from the space between the top row of 2-inch tubes and the steam tubes between back cross box and drum to the middle of the fifth row of 2-inch tubes from the bottom, and placed 2 feet 6 inches from the front end of tubes. The flames pass around the lower edge of the second baffle and thence into the uptake, the opening for which is in the top casing immediately back of the drum. The division of the space above the 2-inch tubes from the second baffle to the top casing is formed by two plates of No. 10 B.W.G. steel with ½-inch asbestos board between, stiffened by an angle and bolted to the cast-iron sectional baffles and to the cross channel bar at top supporting the uptake.

A course of fire bricks is fitted on each side of the tube nest near the top of the nest, supported upon the outside row of the outside header at each side and the inside rows of the corner boxes, to close up the large direct passages existing at these points.

The boiler casing is built in accordance with the usual practice of the Company, except that the outside casing plates are made lighter than in former designs, being No. 16 B.W.G. thick. Next the tubes and fitting them are placed fire tiles about 2 inches thick; next a sheet of ¼-inch asbestos board; then 2 inches of block magnesia, and outside of this the casing

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ASSEMBLING THE ELEMENTS.

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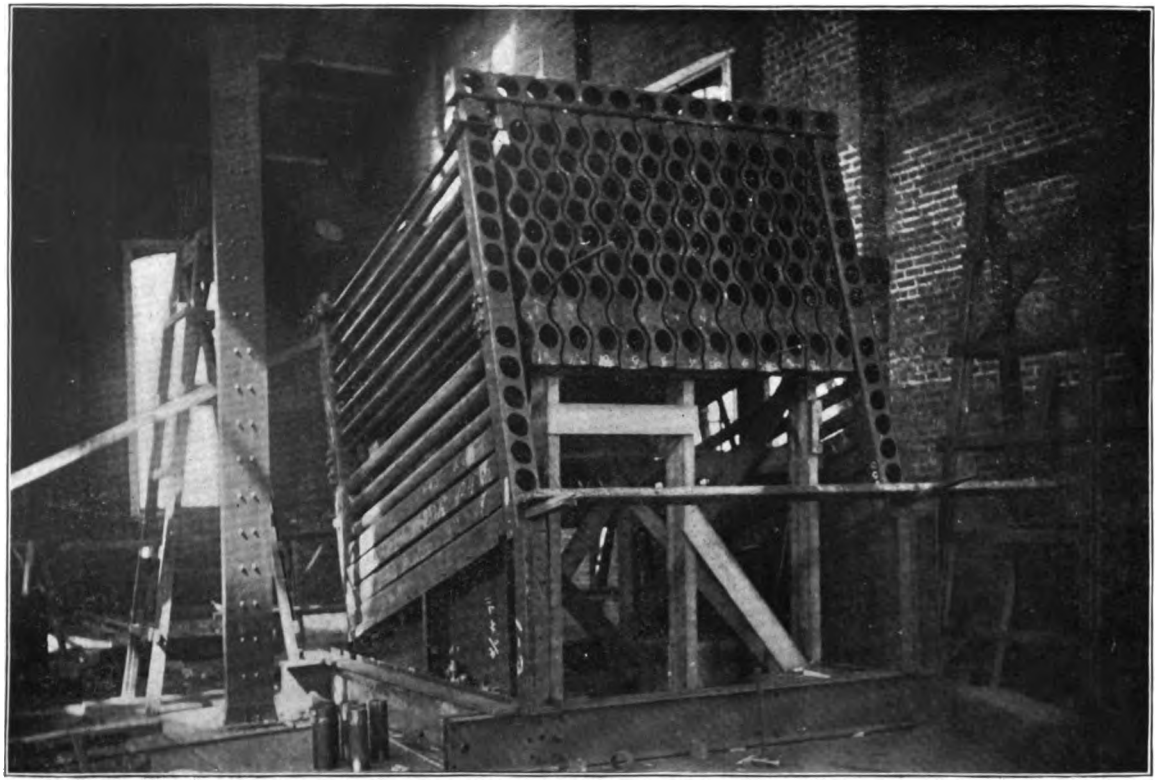

SHOWING ARRANGEMENT OF CORNER BOXES.

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plates. The latter, and by them the fire brick and magnesia lining, are held in place against the frame work, which is built of angles and secured to the boiler foundation by means of straps held in place by studs and nuts, the studs screwed into the flanges of the angles composing the frame work. This construction makes the work of taking down the casing and exposing the tubes and baffles the work of a few minutes. Opposite each of the three flame spaces, *i. e.*, the tube spaces between the vertical baffles and between these baffles and the front and back headers, and on each side of the boiler, six 1½-inch nipples are fitted through the casing plate, the magnesia, and into the fire tiles for the purpose of cleaning out the soot by means of an air or a steam jet. These holes also serve as peep holes to observe the extent of the flame. Opposite the 7½-inch space, between the row of 4-inch tubes and the lowest row of 2-inch tubes, are two doors on each side of the boiler, held up by catches as ordinarily used on connection doors. A peep or blow hole is located in each of the doors on one side of the boiler only. These doors taken down give free access to the space mentioned, so that any accumulations may be readily blown or hauled out. A similar door is placed in the casing opposite the space above the 2-inch tubes on each side of the boiler. These doors are wide and deep enough to admit a man to either side of the deflecting plate. Each of these doors was provided with a peep hole. All the peep or blow holes are closed by a shutter. The doors opposite the space between the 4 and 2-inch tubes are built of an outer sheet of No. 10 B.W.G. steel, 4 inches of magnesia, a sheet of ¼-inch asbestos board, and an inside sheet of No. 10 B.W.G. The doors opposite the space above the 2-inch tubes are similarly built up, except that the inside sheets are No. 16 B.W.G. thick. The uptake doors are of No. 16 B.W.G. plate lined with ¼-inch asbestos board.

The air-heating device, which is no part of the *Alert's* outfit, but was improvised for this test (as was also the blower and its ducts), consisted of a rectangular box, 9 feet wide by 6 feet long by 2 feet 6 inches high, containing one hundred and two 3-inch tubes, 6 feet long, through which the air was drawn by the

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blower and among which passed the uptake gases. These gases passed diagonally through the box and circulated among the tubes. The duct leading from the heater to the suction side of the blower was fitted with a large door close to the blower, so that the cooler air of the building could be drawn in and discharged into the ash pit, the heater thereby being cut out. The blower was an ordinary fan blower, diameter of fan 26¾ inches, driven by a single-cylinder engine.

The following is additional boiler data:

Tubes and nipples in one boiler:	
364 2-inch tubes, 9 feet 2 inches long (exposed length, 9 feet), B.W.G.	No. 8
18 4-inch tubes, 9 feet 2 inches long (exposed length, 9 feet), B.W.G.	No. 6
14 4-inch tubes, 7 feet 11 inches long, B.W.G.	No. 6
48 4-inch nipples, 3½ inches long, B.W.G.	No. 6
14 4-inch nipples, 12½ inches long, B.W.G.	No. 6
Heating surface outside of tubes, square feet	2,012
Heating surface in boxes, square feet	93
Heating surface in drum, square feet	20
Total heating surface, square feet	2,125
Grate surface (length of grate, 6 feet 4 inches), square feet	48
Ratio H. S. to G. S.	44:1
Air heater:	
Number of tubes	102
Diameter of tubes, inches	3
Length of tubes, feet	6
Heating surface in tubes, square feet	481
Area through tubes, square feet	4.3
Least area between tubes for uptake gases, square feet	7.25
Smoke pipe:	
Diameter, feet and inches	3–6
Height, feet	48
Weight of one boiler, as weighed during construction:	
Pressure parts, pounds	27,352
Casing, lagging, etc., pounds	11,764
Grates, furnace material, ash pans, etc., pounds	4,666
Foundation, pounds	1,239
Fittings, pounds	1,089
Total without water, pounds	46,110
Water at steaming level (boiling point at 200 pounds pressure)	7,660
Total weight with water, pounds	53,770
Total weight of boiler, dry-weighed on car, complete, pounds	46,488

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The weight of water necessary to fill this boiler to steaming level was carefully ascertained.

Weight, in pounds, pumped in.	Total.	Temperature. Degrees F.	Water level in gage glass, inches.
1,916	1,916	55	...
1,845	3,761	53	...
1,864	5,625	55	...
1,870	7,495	54	...
433	7,928	53	0
173	8,101	...	1
190	8,291	...	2
169	8,460	...	3
172	8,632	...	4
201	8,833	...	5

Total water at 5 inches in gage glass (which is at the middle of the drum), is 8,833 pounds, or 7,660 pounds for same level at temperature due to boiling water under 200 pounds pressure.

DESCRIPTION OF TESTS.

Four separate tests were made on April 11th, 12th, 13th and 14th.

The first was with cold air, closed ash-pit draft, and a steam jet in the smoke pipe. Duration, six hours, from 11·15 A. M. to 5·15 P. M. This test was intended to demonstrate the performance, under the conditions stated, of the boiler with the maximum consumption of coal that it is expected to reach in naval practice.

The second test was with open ash pit, a steam jet being used in the chimney to produce a partial vacuum about equivalent to that due to the height of smoke pipe as on the ship, viz: about 0.45 inch of water. Duration, ten and one-tenth hours, from 9·40 A. M. to 7·46 P. M.

The third was with heated air, closed ash-pit draft, and a steam jet in the chimney. The blower drew the air through the heater tubes and discharged it into the back of the ash pit. Duration, six hours, from 10 A. M. to 4 P. M. The conditions as to draft, method of firing and temperature of feed, were, as nearly as possible, the same as in Test No. 1, the object being to establish the effect due to the heating of the air.

In all of the three preceding tests Cumberland coal was used.

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During the first and the greater part of the second test it was George's Creek coal. During the latter part of the second test and throughout the third test another shipment of coal, also Cumberland, was used. This last coal contained less slack and less surface moisture than the first, but all was of excellent and presumably of very similar quality.

The fourth test was with cold air closed ash-pit draft, and a steam jet in the chimney. The coal used was anthracite, Lackawanna egg. Duration of test, six hours, from 9·40 A. M. to 3·40 P. M.

The tests were all conducted in a similar manner, the methods of taking and recording data and the time intervals at which recorded being the same throughout. Such remarks and explanations as are essential are found under the following detailed account of the several tests undertaken.

Tests Nos. 1 and 3 were for maximum rates of combustion, and the boiler pressure maintained was the maximum at which the boiler may be safely worked.

Test No. 2 was undertaken under the conditions as to draft and steam pressure as they will exist on the ship for which the boilers are intended.

Test No. 4 was undertaken to show the efficiency of the boiler using hard coal under moderately strong forced draft.

Attention is especially directed to the comparative results of tests made April 13th in presence of the Board, and on April 19th by the firm. These two tests were made under nearly identical conditions as to draft, temperature of feed, and method of firing, except that during the test of April 13th the air heater was in use, while on April 19th it was not, and would seem to show that with the ratio of grate to heating surface, and the circulation of gases secured in the boiler under test, the uptake gases escape at so moderate a temperature that the air heater is of little value. The data of these tests, bearing on this point, are given in a separate table, page 302.

The results of the parallel tests with and without air heaters in use, made by the Board on April 11th and on April 13th, are somewhat vitiated by the fact that the coal used was not from

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the same shipment in the two cases; and, while from the same coal region, and presumably of very similar heating value, the first lot contained about 4.09 per cent. of surface moisture, and was composed of nearly 75 per cent. slack; while the second lot contained 2.77 per cent. of surface moisture, and contained much less slack, about 50 per cent.

The following experiment, made April 22d, in the presence of Chief Engineer G. W. McElroy, U. S. Navy, gives the time required for raising steam under the conditions stated.

Fires were started with wood and oily waste in front. About one-half shovelful of kerosene was thrown on just after lighting the fires. Soft coal was used toward the end. The boiler was at atmospheric temperature when fires were lighted, the water at a temperature of 54 degrees Fahrenheit. Its height in the gage glass on starting fires was 1¼ inches. Almost immediately after fires were started the circulation of the water began, as evidenced by the temperature of the different parts of the boiler.

RECORD OF RAISING STEAM.

Time.		
11·31.	Lighted fire.	1¼ inches water.
11·42.	Began to make steam.	
11·44½.	5 pounds pressure on gage.	
11·45.	10 pounds pressure on gage.	
11·46¼.	20 pounds pressure on gage.	
11·47.	25 pounds pressure on gage.	
11·48¾.	40 pounds pressure on gage.	
11·49¾.	50 pounds pressure on gage.	
11·51.	65 pounds pressure on gage.	4¼ inches water. Put on blower.
11·51¾.	75 pounds pressure on gage.	
11·52¾.	100 pounds pressure on gage.	
11·53.	105 pounds pressure on gage.	
11·53¾.	125 pounds pressure on gage.	
11·54¾.	150 pounds pressure on gage.	
11·55¾.	175 pounds pressure on gage.	
11·56¾.	200 pounds pressure on gage.	
11·57¾.	225 pounds pressure on gage.	5½ inches water. Blew safety valve. Stopped blower.

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Test No. 1 made April 11, 1899. Cold air, closed ash-pit draft, steam jet in the smoke pipe. Duration, six hours, 11·15 A. M. to 5·15 P. M.

Fires were started in the boiler at 8·30 A. M. April 11th, and the test began at 11·15 A. M. and continued for six hours. At the beginning of the test the fires were judged and the water level and steam pressure noted. At the end of the test the fire, water level and steam pressure were again noted, the conditions being as nearly as possible, and, so far as could be judged, identical with those obtaining at the beginning.

The steam gage, barometer, thermometers, pyrometers and high-grade thermometers, draft gages and scales were not standardized, but were of standard make, and no doubt exists as to their substantial accuracy.

The data was taken at 20-minute intervals, the first period being 15 and the last 25 minutes long. The boiler was located in a well-lighted and ventilated end of the shop, remote from machinery and furnaces of any kind, and the fire-room temperatures recorded are no index of the heat radiated from the boiler. The pressure in the ash pit was that near the front of the boiler. The pressure in the smoke pipe was that existing above the heater tubes. The pressure in the furnace was only imperfectly recorded during this test, the mean of two readings at the front giving a vacuum of 0.42 inch of water, the mean of four readings at the back giving a vacuum of 0.20 inch.

The pyrometer recording the uptake temperatures was placed just above the top of air-heater tubes.

During this test the air heater was not in use and the blower drew its air from the building and discharged it into the back of the ash pit. The temperature of the entering air was not recorded, but it may be safely assumed to have been about 60 degrees.

The draft was produced by the blower, running at an average of 442 turns, and by a jet in the smoke pipe, placed about 5½ feet above the top of the air heater. It is to be noted that a steam jet was used on all trials in conjunction with the blower, which latter delivered into a closed ash pit. There were two reasons

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for employing the jet to reach the desired coal consumption per square foot of grate: one was that the blower was too small to create the necessary pressure and deliver the needed supply of air; the second was that, as no damper was provided for closing off the air delivery when furnace doors were opened, it was deemed expedient to maintain negative air pressure in the furnace to prevent the flames from being blown out whenever furnace doors were opened.

It was demonstrated, however, that by closing up the air holes in the dead plate, passing air from the ash pit over the top of the fire through only the holes in the furnace-door liners, which are of cast iron, a pressure of ½ inch could be maintained in the ash pit without danger to the fireman and with the steam jet closed down. This result was made possible by the inclination of the sides of the furnace-door liners, which was such as to direct the jets of air back into the furnace.

The water fed into the boiler was run into an upper weighing tank, where it was moderately heated by a jet of steam, and from which it was allowed to flow into the feeding tank placed directly below. More extensive heating of the feed water was made impracticable by the feed pump, which was too small for the work, refusing to do its duty when the feed temperature was increased much beyond that recorded. The test began with the lower or feeding tank full and ended in the same way.

The coal burned was Cumberland George's Creek, and was of good quality, making little adhesive clinker and containing 7.39 ash. It contained about 75 per cent. slack. The contained moisture was found to be 4.09 per cent., determined by weighing pans containing 80 pounds of moist coal after drying for about 24 hours above the boiler drum.

The calorimeter used was the Barrus throttling calorimeter, such as is generally used for work of this kind, and of which a detailed description is not necessary here.

The calculated quantities are found in Tables I and II. In these calculations the evaporation is given per pound of dry coal. One set of figures gives the potential evaporation based on the steam generated in the boiler under the stated conditions as to

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temperature of feed, pressure and quality of steam. A second set, including in addition the heat absorbed by the evaporation of the moisture in the coal into steam at atmospheric pressure and superheating the same to the average temperature of the uptake gases, was obtained but not herein recorded.

The firing was done by the same man in this and in subsequent tests. He had little experience in firing a boiler under forced draft, and at the beginning of the test the pyrometer showed much more violent fluctuations than toward the close. At no time, however, was antimony melted. The coal was fired close to the doors, where it was coked, and was then worked back by a hoe. The slicing was done entirely through the slicing doors provided. The method of firing was in no wise different from that which would have been followed in firing a Scotch boiler. With closed furnace doors there was little or no smoke to be observed, but whenever a door was opened for coaling or for pushing back the fire, dense clouds of dark-gray smoke at once made their appearance, to disappear immediately after furnace doors were closed.

Frequent observations were made to note how far the flame extended. It was plainly noticeable at the top of the first baffle and for a part of the distance down between the first and second baffles, but never showed beyond the second baffle. At the back end of the sides of the boiler casing the outside casing plates were too hot to bear the hand against opposite the furnace and for some distance up, the temperature gradually decreasing upward and toward the front, where the hand could be held against them without discomfort. In two spots the casing plate became hot enough to bulge slightly. In one spot, at about the middle of the height and length of the tube nest, a brick had been partially broken when drilling through for the peep and blow-hole thimble; at another spot, opposite the furnace, near the boiler front, a space had been left unpacked between the square tubes forming the furnace sides.

A number of analyses of flue gases was made on this and on each of the subsequent tests by means of a portable Orsat appa-

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SHOWING BAFFLES AND DRUM CONNECTIONS.

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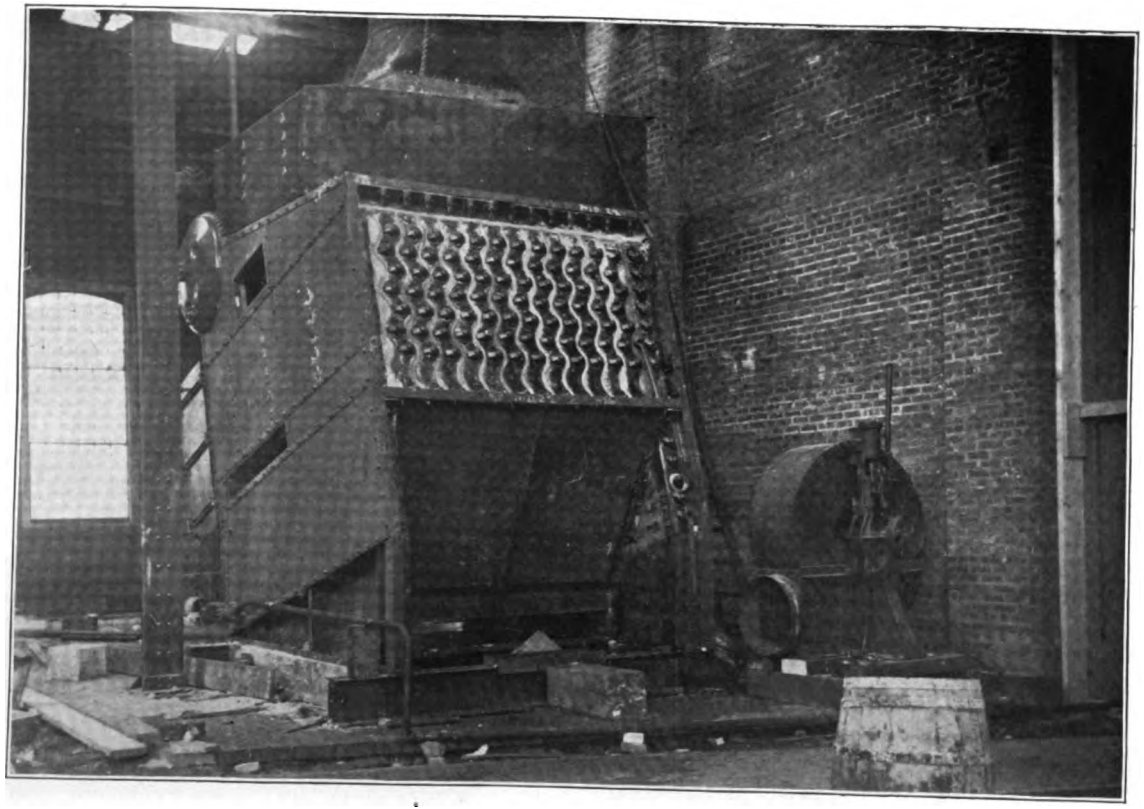

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ratus. The record of the results of these analyses is found for all the tests on page 299.

The steam made by the boiler was used to work its own auxiliaries, for the jet, for heating the feed water, and for the shop engines. The pressure was regulated by a stop valve worked by hand. Occasionally it became necessary to relieve the pressure by opening a stop valve allowing steam to escape to the atmosphere. The safety valve was set to 225 pounds and never lifted.

Besides the feed connection there was only a bottom blow valve and pipe connecting with the boiler-water space. The end of the pipe was exposed and no leak occurred.

Test No. 2, made April 12, 1899. Duration 10.1 hours, from 9·40 A. M. to 7·46 P. M. Jet in the smoke pipe to produce a vacuum equivalent to about 0.45 inch of water.

This test was undertaken to show the probable performance of the boiler under the conditions expected to obtain on board the vessel for which the boilers are intended.

It was made with the standard start and finish; *i. e.*, fires were hauled at the beginning of the test, furnace and ash pits cleaned of refuse, and a new fire started with a weighed amount of wood. At the end the fires were allowed to burn down, and the refuse left in furnace and ash pit weighed in a dry state.

Data were taken at twenty-minute intervals. First: Time, steam pressure, barometer, temperature of the steam, temperature of the uptake gases, temperature of the air, temperature of the fire room, draft at base of smoke pipe, draft in back of furnace.

Second: Records of the weight of water fed into the boiler. The feeding tank was full at the beginning and at the end of the test. There was a recorded difference of $\frac{3}{8}$ inch in the height of water in the gage glass at the beginning and at the end of the test. No account was taken of this unimportant difference in making the calculations, as the water level fluctuated very much at the beginning while fires were being hauled and relighted, and an accurate reading of the gage was impossible. The temperature of the feed water is also given in this table.

Third: Records of the coal burned, together with the refuse

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from the coal and the contained surface moisture. It also gives particulars of the start and the kind of coal used.

Fourth: Records of the tests for quality of steam, and gives the data for correction of the quality due to condensation in the instrument.

Tables I and II contain the calculated results and final averages. The evaporation has been figured out on the basis of dry coal and combustible consumed and water evaporated into steam of the calculated quality.

Test No. 3, made April 13th, 1899. Duration, six hours, from 10 A. M. to 4 P. M. Conditions as nearly as possible the same as in Test No. 1, except that the air heater was in operation.

This test was undertaken under as nearly as possible the same conditions as to draft, coal consumption, steam pressure and temperature of feed as obtained in Test No. 1, the only difference being that the air heater was in use, the object being to determine its effect on the potential and economic performance.

The coal used was the same as that used during the latter part of Test No. 2. The coal used during Test No. 1 was Cumberland coal, George's Creek, containing about 75 per cent. slack, and 4.09 per cent. of surface moisture. The per cent. of refuse was 7.09 of the wet coal and 7.39 of the weight of dry coal. The coal burned on Test No. 3, and which was also used during the latter part of Test No. 2, as noted, was also Cumberland coal of another shipment. It contained about 50 per cent. of slack, and 2.77 per cent. surface moisture. The refuse was 10.21 per cent. of the weight of the wet, and 10.5 per cent. of the weight of dry coal. There was presumably little difference in the calorific value of the two lots of coal used, but the fact that the identical coal was not used on both tests renders the results not strictly comparable.

The explanation of tables is the same as for previous tests.

Test No. 4, made April 14th, 1899. Duration, six hours, from 9·40 A. M. to 3·40 P. M. Cold air ash-pit draft, steam jet in the smoke pipe.

This test was made to show the performance of the boiler under moderately strong forced draft using hard coal.

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For details refer to the tables, the explanation being as in preceding tests.

ANALYSES OF FLUE GASES MADE BY A PORTABLE ORSAT APPARATUS.

Time.	CO_2.	O.	CO.	Remarks.
	per cent.	*per cent.*	*per cent.*	
		TEST No. 1. APRIL 11TH, 1899.		
1·20	10.0	8.6	0.6	Just before firing.
1·30	11.7	7.3	0.0	Just before firing.
1·40	11.2	6.8	0.0	Between firings.
2·52	9.0	10.0	0.0	Just before firing.
3·48	10.8	6.5	1.0	Just after firing.
4·07	11.3	8.2	0.5	2½ minutes after firing.
4·47	10.7	7.7	1.1	2 minutes after firing.
5·06	10.7	7.3	1.0	Just before firing.
Averages...	10.7	7.8	0.5	
		TEST No. 2. APRIL 12TH, 1899.		
12·25	9.4	7.6	0.6	Between firings.
2·00	9.3	9.0	0.0	2 minutes after firing.
3·00	11.0	8.0	0.0	Just before firing.
3·12	10.7	7.5	0.6	1 minute after firing.
5·30	11.8	7.2	0.0	Just before firing.
6·20	10.7	8.3	0.0	1 minute after raking.
...	12.2	6.2	0.3	1 minute before firing.
Averages...	10.9	7.7	0.02	
		TEST No. 3. APRIL 13TH, 1899.		
11·20	11.0	7.0	0.0	1 minute after raking.
12·00	10.0	9.7	0.0	Just before firing.
12·12	11.0	9.1	0.0	1 minute after firing.
1·30	12.0	6.4	0.3	1 minute after firing.
2·55	10.5	8.5	0.0	Between firings.
Averages...	10.9	8.1	0.06	
		TEST No. 4. APRIL 14TH, 1899.		
10·45	10.8	9.0	0.0	
12·12	11.6	7.8	0.0	
1·18	11.2	9.0	0.0	
2·05	11.7	8.0	0.0	
2·30	10.0	10.1	0.0	
3·15	11.1	8.2	0.0	
Averages...	11.1	8.7	0.0	

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TABLE I.

	Test No. 1. April 11, 1899.	Test No. 2. April 12, 1899.	Test No. 3. April 13, 1899.	Test No. 4. April 14, 1899.
Average steam pressure, absolute, p	234	128.4	234.6	232.8
Average temperature of the feed water, t_1	94.5	110.0	91.5	111.0
(a) Number of pounds of water vaporized, $W_1 \times Q$ ..... $104{,}476 \times .9989 =$	104,361	89,969.0	102,255	76,008
(b) Number of pounds of water carried over with the steam, $W_1 (1 - Q)$	115	36.0	102	38
Total heat of steam at pressure p	1,202.5	1,190.1	1,202.6	1,202.4
Total heat of water at temperature t_1	62.5	78.0	59.5	79.0
(c) Units of heat required to vaporize one pound of water from a temperature t_1 and under a pressure p	1,140.0	1,112.1	1,143 1	1,123.4
(c^1) Units of heat required to raise the temperature of one pound of water from t_1 to the temperature due to the pressure p	306.1	248.3	309.3	289.2
(d) Units of heat required to vaporize one pound of water from and at a temperature of 212 degrees and under atmospheric pressure	965.7	965.7	965.7	965.7
Total heat required to vaporize the water, $a \times c$	118,971,540	100,054,525	116,887,691	85,387,387
Total heat required to raise the temperature of the water, $b \times c^1$	35,202	8,939	31,549	10,990
(e) Total heat obtained from the fuel, as measured by the steam discharged	119,006,742	100,063,464	116,919,240	85,398,377
(f) Units of heat obtained per pound of fuel	9,104	10,386	9,643	10,289
(g) Units of heat obtained per pound of combustible	9,831	11,380	10,830	11,735
$\frac{f}{c}$ Potential evaporation per pound of fuel, from a temperature t_1 and under a pressure p	7.99	9.34	8.44	9.16
$\frac{g}{c}$ Potential evaporation per pound of combustible, from a temperature t_1 and under a pressure p	8.62	10.23	9.47	10.45
$\frac{f}{d}$ Equivalent potential evaporation per pound of fuel, from and at a temperature of 212 degrees and under atmospheric pressure	9.43	10.76	9.99	10.66
$\frac{g}{d}$ Equivalent potential evaporation per pound of combustible from and at a temperature of 212 degrees and under atmospheric pressure	10.19	11.78	11.22	12.16

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TABLE II.—RECAPITULATION OF THE RESULTS OF THE EVAPORATIVE AND CALORIMETRIC TESTS OF BABCOCK & WILCOX BOILER FOR U. S. S. *ALERT*.

Test No. 1 was made at the works of the Babcock & Wilcox Company; Tests Nos. 2, 3 and 4, at Elizabethport, N. J.

NOTE.—All weights are given in pounds and all temperatures in degrees Fahrenheit.

Total quantities.	Test No. 1. April 11, 1899.		Test No. 2. April 12, 1899.		Test No. 3. April 13, 1899.		Test No. 4. April 14, 1899.	
Duration of test, in hours	6		10.1		6		6	
Fuel consumed* (dry coal)	13,073		9,634		12,063		8,300	
Refuse from fuel, in dry ashes, dust and clinkers	967		846		1,267		1,023	
Combustible consumed	12,106		8,788		10,796		7,277	
Water fed to boiler, by tank measurement, W_1	104,476		90,005		102,357		76,046	
Per cent. of the fuel in dry refuse, etc., (of dry coal)	7.39		9.0		10.5		12.33	
Average quantities.								
Temperature of feed water, t_1	94.5		110		91.5		111	
Temperature of steam, by thermometer	383.2		346		383.4		384.2	
Temperature of uptake	619		445		572.7		521	
Temperature of atmosphere	55.1		52.4		64.9		62	
Temperature of fire room	71.0		66.3		96.1		83.75	
Barometer, in inches of mercury	30.27		29.92		30.0		29.81	
Temperature of air entering heater tubes	.....		.....		84.1		.....	
Pressure of steam at boiler, in lbs. per sq. in. above a perfect vacuum, 15 + press. by gage in lbs., p,	234		143.4		.....		232.8	
Temperature of air entering ash pit	.....		.....		165.5		.....	
Air pressure, in inches of water, in ash pit	(+) 0.53		(—) 0.14		(+) 0.51		(+) 0.55	
Air pressure, in inches of water, at furnace front (mean of two readings)	(—) 0.42		(—) 0.43		(—) 0.24	(—) 1.41	(—) 0.07	
Air pressure, in inches of water, in smoke-pipe	(—) 1.43		.....		569		410	
Revolutions of blowing engines, per minute	442		.....		.....		.....	
Rates of combustion.	Lbs. fuel.	Lbs. combustible.	Lbs. fuel.	Lbs. combustible.	Lbs. fuel.	Lbs. combustible.	Lbs. fuel.	Lbs. combustible.
Amount consumed per hour	2,178 67	2,017.5	953.86	870.1	2,010.5	1,799.33	1,383.33	1,212.83
Amount consumed per hour per sq. ft. of grate surface	45.39	42.03	19.88	18.13	41.88	37.49	28.82	25.27
Amount consumed per hour per sq. ft. of heating surface (exterior)	1.03	0.95	0.449	0.409	0.95	0.85	0.65	0.57
Vaporization in pounds of water.	Per lb. fuel.	Per lb. combustible.	Per lb. fuel.	Per lb. combustible.	Per lb. fuel.	Per lb. combustible.	Per lb. fuel.	Per lb. combustible.
Apparent evaporation, by tank measurement, from a temperature t_1 and under a pressure p	7.99	8.63	9.34	10.24	8.49	9.48	9.16	10.45
Equivalent apparent evaporation from and at 212 degrees and under atmospheric pressure	9.43	10 18	10.76	11 80	10.05	11.22	10.66	12.16
Actual evaporation, into steam of quality Q, from a temperature t_1 and under a pressure p	7.98	8 62	9.34	10.24	8.48	9.47	9.16	10.45
Equivalent actual evaporation from and at 212 degrees and under atmospheric pressure	9.42	10.18	10.76	11.79	10 04	11.21	10.66	12.15
Potential evaporation, or evaporation had all the heat obtained from fuel been utilized in converting the water in boiler into dry saturated steam from a temperature t_1 and under a pressure p	7.99	8.62	9.34	10.23	8.44	9.47	9.16	10.45
Equivalent potential evaporation from and at 212 degrees and under atmospheric pressure	9.43	10.19	10.76	11.78	9.99	11.22	10.66	12.16
Potential evaporation, taking account of evaporation of moisture in the coal, from temperature t_1 and under pressure p	8 03	8.68	9.38	10.29	8.51	9.51	.....	.....
Equivalent potential evaporation from and at 212 degrees	9.49	10.25	10.81	11.85	10.08	11.26	.....	.....

* Test No. 1, Cumberland, George's Creek, Hofmann's Big Vein; Test No. 2, Cumberland, George's Creek (dry coal + .4 × weight of wood); Test No. 3, Cumberland, George's Creek (dry); Test No. 4, Anthracite, Lackawanna Egg.

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EXAMINATION OF THE BOILER AFTER THE TESTS HAD BEEN CONCLUDED.

Comparison of data of trials, with and without the air heater, bearing on efficiency of latter as referred to on page 292. Conditions otherwise nearly identical.

	April 13. In presence of Board. Air heater in use.	April 19. By builders. Without air heater.
Duration of test, hours	6	6
Kind of coal	Cumberland.	Cumberland.
Draft, stack, inches	1.40	1.41
Blast, inches	+ 0.51	+ 0.41
Temperature air, ash pit, degrees Fahr.	168	67
Water per hour, pounds	17,083	16,320
Coal per hour, dry	2,010.5	1,917.5
Coal per hour per sq. ft. grate surface	41.88	39.93
Water per pound coal per hour	8.49	8.51
Water per pound coal per hour from and at 212 degrees Fahrenheit	10.06	10.05
Temperature of flue gases, degrees F.	562 to 572	578 to 584

On the completion of the tests the boiler was thoroughly examined inside and outside.

The grate bars and bearers had not suffered the least injury, nor did the fire-brick back or the fire-brick baffles supported upon the row of 4-inch tubes over the furnace show signs of distress.

The entire outer casing plates opposite the tubes were removed on one side and the magnesia and fire-brick lining taken down, exposing the tubes and making possible an examination of the sectional vertical baffles. These, as well as the inclined deflector in the space above the tubes, were found in perfect condition. The edges were sharp, and no warping was noticeable. The 4-inch tubes immediately above the furnace were perfectly straight.

A number of the handhole plates at the back end of the boiler were leaking more or less, but the correction due to the evaporation of the water that leaked out into steam at atmospheric pressure, instead of into steam at boiler pressure, is negligible.

Generally speaking, the tests conducted must be regarded as most satisfactory. The boiler did its work under natural and under forced draft with good economy and without distress.

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The comparatively low temperature of the uptake gases during all the tests both with and without the air heater in use seems to indicate that the air heater is not a necessity in combination with a boiler of the design under consideration, and cannot be considered a desirable adjunct except, possibly, when working at very high rates of combustion.

The accompanying photographs represent this boiler in different stages of its construction and illustrate the simplicity of the entire apparatus.

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RECENT TRIALS OF THE MACHINERY OF BRITISH WARSHIPS.*

In the following paper the authors propose to give a brief account of the recent extensive developments in marine engineering practice in the Royal Navy; and to complete the record of particulars of, and the results obtained from, the machinery of warships since the period dealt with in the paper † read before the Institution in November, 1894. In the tables of the appendix there are accordingly presented, for battleships, cruisers and torpedo-boat destroyers, respectively, data of practically the same character as given in the previous paper. An additional column has been added, giving the coal consumed per I.HP. per hour, which was generally not available for the older vessels; and a slightly different arrangement has been adopted. The weight of machinery has been given in pounds per I.HP., divided between engines and boilers; while the I.HP. per ton of engines and boilers respectively, the form in which weights were expressed in the former paper, is also given. To facilitate comparison, the corresponding mean results for similar ships built under the Naval Defense Act, which immediately preceded those about to be reviewed, are given at the head of the respective tables.

An Admiralty Committee was appointed to inquire into the designs of machinery for warships, and presented its report in 1893. One of the more important recommendations was to the effect that the water-tank boilers should be so proportioned as to have 2.5 square feet of total heating surface per horse-power developed on the eight-hours natural-draft trial, and that the power developed on the four-hours forced-draft trial should

* By Sir Albert John Durston, K. C. B., R. N., M. Inst. C. E., and Henry John Oram, R. N., M. Inst. C. E.

† "The Machinery of Warships," Minutes of Proceedings Inst. C. E., vol. cxix, p. 1.

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be limited to 25 per cent. in excess of the natural-draft power. This recommendation was adopted by the Admiralty with the exception that the forced-draft power was limited to 20 per cent. beyond the natural-draft power, instead of 25 per cent. as recommended by the Committee. The boilers of vessels designed prior to this period had less surface per horse-power, and the effect of the adoption of proportionately larger boilers will be seen in the comparison of weights of water-tank boilers dealt with in this and the preceding papers.

In Table I particulars are given of the ten battleships tried with water-tank boilers; they are of similar design, and are all arranged to develop 10,000 I.HP. with natural draft (eight hours), and 12,000 I.HP. with accelerated draft (four hours). They have each two sets of triple-expansion engines having cylinder ratios of 1 : 2.18 : 4.8, the dimension of cylinders, stroke of engines, and steam pressures being exactly the same as in the preceding eight battleships. They all have eight single-ended four-furnace boilers, each with two combusion chambers, except in the boilers of the *Renown*, which have four combustion chambers, one to each furnace. The boilers are arranged two in each of four watertight compartments, with their backs towards the middle-line bulkhead of the ship, and stokeholds in the wings. While the boilers were of larger dimensions than those of the vessels under the Naval Defense Act, the engines were also made of rather more substantial construction, and for these two reasons the horse-power realized per ton is less than in the corresponding eight vessels of the Naval Defense Act. All these battleships obtain their maximum power by forced draft fitted on the "closed-stokehold" system, with the exception of the *Magnificent* and *Illustrious*, where fans in the uptakes are fitted on the system known as "induced draft," to which reference is made later. It will be seen from Table I that the amount of forcing, as indicated by the air pressure or vacuum required, is but moderate, and the maximum powers were easily obtained. The boiler tubes are all fitted with the Admiralty cap ferrules, and leaky boiler tubes, once so fruitful of trouble in warships, are now practically unknown.

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The six battleships of the *Canopus* class given in Table I are now reaching their trial stage, so that their actual performances cannot yet be given, but where I.HP. is involved the data given is based on the estimated powers. These vessels have three-cylinder triple-expansion engines, with cylinder ratios of 1 : 2.7 : 7.1, the increased pressure employed enabling the higher ratio to be fitted with advantage. Steam is supplied by twenty Belleville boilers with economizers, arranged in three watertight compartments. They are placed four abreast athwartships, the aft four in one compartment, and the others grouped back to back, eight together, in each of the other compartments. The result is a considerable increase in the I.H.P. per ton of boilers and the I.H.P. per ton of machinery complete.

The next vessels, six in number, are of the *Formidable* class; their machinery is similar, though slightly more powerful, than the last named, and need, therefore, not be further described.

Table II shows the first-class cruisers, and the first dealt with are the *Powerful* and *Terrible*. These have triple-expansion four-cylinder engines with cylinder ratios of 1 : 2.4 : 5.7. The two low-pressure cylinders are placed aft with the intermediate cylinder between these and the high-pressure; steam is supplied by forty-eight Belleville boilers without economizers, which are arranged in eight watertight compartments, four on each side of a longitudinal middle-line bulkhead, the four after compartments having eight boilers in each, and the four forward four in each. In the compartments having eight boilers the latter are arranged two abreast athwartships, divided by two stokeholds, and are stoked in the fore-and-aft direction. In the compartments having four boilers they are arranged with backs towards the middle-line bulkhead, and are stoked from the wings. The installation provides a heating surface of 2.7 square feet per I.H.P. at the maximum specified power. A comparison with the first-class cruisers built under the Naval Defense Act shows an increase in both I.H.P. per ton of boilers and of machinery complete.

The next four first-class cruisers in table II have four-cylinder triple-expansion engines, arranged in the same order as in *Powerful* and *Terrible*, and having cylinder ratios of 1 : 2.66 : 7.08.

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The boiler installation consists of thirty Belleville boilers with economizers arranged athwartships in four watertight compartments. The I.H.P. per ton of machinery is slightly less than in *Powerful* and *Terrible*, due partly to the greater cylinder ratios adopted. The steam pressure employed was increased, being 300 pounds per square inch at boilers, reduced to 250 at engines, as compared with 260 pounds and 210 pounds respectively in the *Powerful* and *Terrible*.

The four first-class cruisers next ordered, *Argonaut*, etc., have cylinders of the same dimensions as those last described, but in *Ariadne* and *Spartiate* these are arranged with one low-pressure cylinder forward of the high-pressure, and one abaft the intermediate-pressure. The greater power is obtained at the engines by adopting a higher speed of revolution. They have the same number and arrangement of boilers but with greater heating surface. The I.H.P. per ton of machinery shows an increase due to the higher speed adopted.

Referring now to the second-class cruisers, detailed in Table III, the nine vessels first mentioned have triple-expansion three-cylinder engines with cylinder-ratios of 1 : 2.2 : 5.0. Steam is supplied by eight single-ended water-tank boilers, three furnaces in each, with a separate combustion chamber to each furnace. The boilers are arranged in two watertight compartments, two abreast, back to back, with stokeholds athwartships. The I.H.P. per ton of machinery and boilers is less than in the average of the ships built under the Naval Defense Act, the boilers being all single-ended, as compared with three double-ended and two single-ended in the majority of the earlier ships. The four next-named vessels have three-cylinder triple-expansion engines, with cylinder ratios of 1 : 2.6 : 6.8; and are fitted with eighteen Belleville boilers without economizers, arranged in three watertight compartments, the boilers being three abreast, back to back, with stokeholds athwartships. An increase is shown in the I.H.P. per ton of machinery and boilers over the nine preceding vessels, and also as compared with the Naval Defense Act ships.

The third-class cruisers are shown in Table IV, and the group of nine vessels first occurring are supplied with fast-running

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three-cylinder triple-expansion engines having cylinder ratios of 1 : 2.59 : 6.93. They have eight water-tube boilers of the small-tube type, placed in two watertight compartments. The four boilers in each compartment are arranged two abreast, back to back, with stokeholds athwartships. Table IV clearly illustrates the saving in weight due to this class of machinery. A comparison with the *Pearl* class, built under the Naval Defense Act, shows that the same I.H.P., viz: 7,000, has been attained with a saving of weight of about 150 tons. The engines are now all fitted with balance weights, and are consequently free from objectionable vibration. The latest vessels of the class are fitted with four-cylinder triple-expansion engines.

A very numerous and interesting class of ships will next be dealt with, viz: the torpedo-boat destroyers, particulars of the trials of a large number of which are given on Table V. The first vessels of this class were nearly all of 27 knots speed (a few were of 26 knots), but subsequently a considerable number have been constructed of 30 knots speed and over. The engines are all of the triple-expansion type, with either three or four cylinders, the stroke being in the majority of cases 18 inches and number of revolutions 350 to 400 per minute. Water-tube boilers of various designs of small-tube type are fitted in them. The number of boilers in each vessel is either three or four, and at full power one H.P. is generally realized on about two square feet of heating surface. Six of the earliest vessels had locomotive boilers, but all these have proved unsatisfactory and either have been or are being replaced by water-tube boilers. The longest stroke being fitted is 21 inches, which at 400 revolutions per minute gives a mean piston speed of 1,400 feet per minute. The smallest ratio of high to low-pressure cylinder volumes fitted is 1 : 4.03 and the largest is 1 : 6.18, this ratio having gradually increased in the later vessels. The steam pressure varies considerably, the maximum being 250 pounds per square inch. The machinery and boilers of such vessels, in order to obtain the high speeds necessary, have to be of the lightest possible description, and columns 18 to 22 of Table V show that considerable reductions in weight below that of ordinary machinery have been made.

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The necessity of so reducing weight is most important, as each increase adds to the displacement of the ship, and thus requires additional power to propel it and additional coal to maintain the power. Such vessels are only made possible by the employment of a high speed of revolution for the engines, and the adoption of dimensions which subject all the parts to the maximum safe limit. The boilers have also to be forced to a high degree, and the materials adopted must be of the highest quality and subject to more than usually searching tests before use. The consequent lightening of the machinery which results is, however, only obtained at the expense of its durability, while at the same time accidents in such vessels are more numerous than in others. Experience is now indicating the modifications necessary in order to minimize them, but the propulsion of such vessels at speeds of thirty knots and over must always involve the acceptance of greater risks than ordinarily involved in warship machinery. In one such vessel now under construction, the *Viper*, Parsons marine steam turbines are being fitted in conjunction with four shafts and eight propellers. The approaching trials of this vessel and experience as to the behavior and economy of the rotary engines will be awaited with interest. The number of vessels dealt with in these five tables is considerable, and indicates the large additions which have been made to the Navy during the last few years.

Number of Cylinders.—Until recently the triple-expansion engines of large ships were invariably of the three-cylinder type, but in the later vessels, as will have been noted from the preceding descriptions, four-cylinder arrangements have become general, the low-pressure being divided into two separate cylinders. The first large engines so fitted in the Royal Navy were those of the *Powerful* and *Terrible*. Had only one low-pressure cylinder been fitted in these vessels for each screw, the diameter would have been 108 inches, an undesirably large dimension for the speed of revolution and piston speed, which on the contractor's full-power trial averaged about 113 feet and 904 feet per minute respectively. With four cylinders the twisting moments are more uniform, and the moving parts can be more readily arranged to

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minimize the forces causing vibration, and thus generally a more smoothly-working engine is obtained. Although the over-all length of the engine itself is thereby increased about 15 per cent. and the weight of engine by about 12 per cent., the arrangement suits the comparatively narrow engine rooms often necessary in warships, especially in cruisers, and has comparatively little effect in increasing the length of engine rooms beyond that required for a satisfactory arrangement of auxiliary machinery. All recent orders for battleships and cruisers have this four-cylinder arrangement specified, while many smaller vessels, such as torpedo-boat destroyers, have engines similarly constructed.

Arrangement or Sequence of Cylinders.—With three cylinders the general sequence is high, intermediate and low-pressure, commencing from forward. In a few cases the arrangement, intermediate, high, low-pressure is adopted, and this, in cases where the crank shafts are in three interchangeable parts, gives a shorter engine, but it increases the lengths of the main steam and receiver pipes, and is not so favorable to ventilation of the engine room. With four-cylinder engines it is usual to place the center lines of each of the two end pairs of cylinders as close together as practicable, the valve gears being at the ends and the cranks of each pair placed at about 180 degrees apart. The forces causing vibration are thus reduced, while the arrangement also permits a reduction to be made in the length of main bearings between these cranks and in the number of engine columns. The arrangements now usually adopted in the Royal Navy are:

(1) Low-pressure.	Low-pressure.	Intermediate.	High-pressure.	Forward.
(2) Low-pressure.	Intermediate.	High-pressure.	Low-pressure.	Forward.

There is little difference between these plans as regards over-all dimensions, but in the former the main steam pipes in the engine room and the receiver pipes are more easily arranged, while the latter renders the flat slide valves of the low-pressure cylinders more accessible. There are many other possible arrangements of these cylinders, such, for example, as the placing of the two low-pressure cylinders forward of the high-pressure and intermediate, and most of these arrangements occur either

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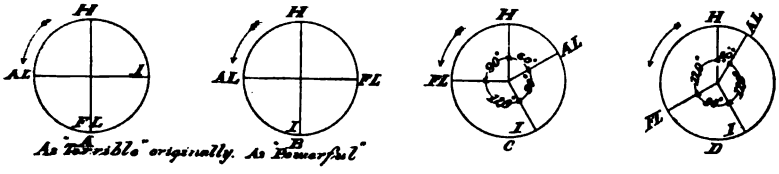
in one or more English warships. Advantages of one kind or another are claimed for each by their advocates, but it is doubtful whether any real advantage is gained over one or other of the two principal plans first referred to.

Distribution of Power between the Four Cylinders.—In some of the earlier designs the details were such that practically equal powers are developed in each cylinder, all the piston and connecting rods, &c., being of the same dimensions. Lately it has been arranged that about one-third of the power should be developed in each of the high-pressure and intermediate cylinders, and one-sixth or a little more in each of the low-pressure cylinders, and the dimensions of the working parts of the latter have been proportioned accordingly.

Slide Valves.—The slide valves are placed in the same fore-and-aft line as the cylinders, and are worked directly from the shaft by ordinary link gear. Except in a few cases, piston slide valves have been fitted in connection with the high-pressure cylinders of engines working at 155 pounds per square inch and over; and in recent engines both the high-pressure and intermediate valves are specified of the piston type, flat valves being allowed on the low-pressure only. In some cases the large, flat, low-pressure valve in three-cylinder engines has been divided into two, one at the forward and one at the after side of the cylinder.

FIGS. 4.



Arrangements of Cranks and Vibration.—In four-cylinder engines the shafts have been usually arranged with the two forward and the two after cranks at 180 degrees to each other, the forward pair being placed at 90 degrees to the after. The engines of the *Powerful* were so arranged, but in the sister ship *Terrible*

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the cranks were at first arranged in regular sequence of 90 degrees to each other, the two low-pressure cranks, which were at the after end, being at right angles, as shown at A in Figs. 4. It will be interesting to compare the results obtained with these engines, neither of which were fitted with any balance weights. The sequence of the cylinders of both ships are as indicated at (1) above, and the cranks were purposely arranged differently, so that a practical comparison should be made. The crank shafts were in four lengths, and twelve bolts were fitted to each coupling. Thus means were provided for easily altering the angles between the cranks to whichever of the two arrangements was found on trial to be the more satisfactory, or to any other angles which were multiples of 30 degrees.

The *Terrible's* arrangement, although superior as regards the uniformity of twisting moments, was found on trial to cause much more vibration than the *Powerful's*, and the vibration was greater than could be permitted when steaming at 86 revolutions up to 92 revolutions per minute. It was determined then to make trials and measurements of the amount of vibration with various arrangements of cranks, the propellers being disconnected from the engines. This was done, and the vertical motion of the extreme stern of the ship was carefully measured by Mr. Mallock, with suitable apparatus, at various speeds of revolution. Calculation had been made giving the forces acting throughout a revolution for the setting of cranks indicated by A, B, C and D in Figs. 4, the resultant of the vertical components of the inertia forces due to the whole of the actual moving weights being found for various points in the complete revolution. The forces were then represented in the usual manner by a single free force acting at the center of the engines with a corresponding unbalanced couple.

The result of the vibration trials is shown in the following table. The calculated free forces and unbalanced couples have their relative maximum values inserted in columns 2 and 3, the force and couple for setting (A) being taken as the standard for comparison, and being represented in each case by unity.

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1	2	3	4	5
Setting.	Calculated maximum unbalanced couple.	Calculated maximum free force.	Actual vertical vibration observed, one engine only at work.	Actual vertical vibration observed, both engines at work.
			inches.	*inches.*
A	1.00	1.00	1.55	Not tried.
B	0.64	2.48	0.80	1.7
C	0.35	12.60	Not tried.	Not tried.
D	0.18	12.50	0.10	Not tried.

Comparing settings A and B—that is, the original *Terrible* and *Powerful* arrangements—it will be seen that a substantial reduction in vertical motion of the stern resulted from B. Setting D gave a vertical motion hardly appreciable, and only $\frac{1}{15}$ that of the original arrangement A. With this arrangement D, although the maximum free force is twelve and a half times as great as in arrangement A, the maximum unbalanced couple is only 18 per cent., so it is inferred that in this case the unbalanced couple is the more important in causing vibration. Both engines were then altered to setting D, and a 15,500 I.H.P. trial for 60 hours was carried out at 94 revolutions per minute, when it was found that, although when tried in dock with propellers disconnected there was practically no vibration, yet at sea a considerable amount was reported. Besides this vibration, however, there were difficulties respecting the quick handling of the engines with the D setting, which was then abandoned, and both engines were altered to the arrangement marked C, at which setting, trials of 18,500 I.H.P. at 98 revolutions and 25,000 I.H.P. with 108 revolutions per minute were run, and tests made at other powers, with the result that vibration with this arrangement of cranks had disappeared.

In the smaller classes of ships, with engines running at high speeds of revolution, vibration of the ship is often very troublesome, but is usually overcome by the addition of balance weights suitably arranged on the crank arms. The best position for these is often determined by practical tests carried out under steam with the propellers disconnected. In many vessels the cranks are originally arranged at angles differing from the usual right-

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angled arrangements in order to minimize the resultant unbalanced forces, and balance weights are also added, either at the cranks or in the form of pistons, heavier than are otherwise necessary.

Induced Draft.—Reference was made in the previous paper* to the trials of induced draft in *Gossamer*, and a brief account was given of the features of the system. The fittings have since been installed in a sloop, the *Torch*, and two first-class battleships, the *Magnificent* and *Illustrious*. A second sloop, the *Alert*, fitted with forced-draft fittings, but in other respects similar to the *Torch*, was built at the same time, and has enabled comparative trials of long duration to be carried out. These have shown no economy in favor of the induced draft, as was the case in the installations used with locomotive boilers, although the advantage of the open stokehold remains. The thirty-hours coal-consumption trials of *Magnificent* and *Illustrious* gave economical results, as will be seen in Table I; but the behavior of the fans and fittings in these ships showed that under certain working conditions these may become heated to an undesirable extent. With the Belleville boiler now adopted for large vessels there is no necessity for much forcing of the boilers, so that the further development of this system of draft is not required, and it has not been repeated.

Water-Tube Boilers.—The type of boiler most suitable for use in warships, as between the water-tank or water-tube type, has been undoubtedly settled during the last few years in favor of the latter. The *Sharpshooter* and *Speedy* marked the experimental stage of the large and small-tube types of water-tube boilers respectively, but extended experience in these vessels and other considerations have now determined the general use of this type of boiler as a steam generator for all warships. In this respect the period covered by this paper marks a step in the development of boilers for warships even more important in its bearing on steam machinery than the successive changes previously made from flue boilers to tubular-box boilers, and from those to the cylindrical return-tube type recently so largely em-

* Minutes of Proceedings Inst. C. E., vol. cxix, p. 30.

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ployed in the Naval service. The tables in the Appendix show how numerous are the forms of this latest type of boiler.

Among the features which will determine the fitness or otherwise of these forms for future use in the Navy are those of weight and space occupied, economy and durability. In respect of these features the various water-tube boilers divide themselves naturally into two classes, viz: (*a*) those with large tubes of considerable thickness, and (*b*) those with small and thinner tubes. Careful consideration and experience have led to the selection, at least for the present, of the Belleville type of large-tube boiler for use in the larger classes of warships. For such ships the question of durability of boilers is of primary importance. As the greater weight of the Belleville boiler, as compared with the small-tube type, is associated with superior economy in coal consumption, in ships of large bunker capacity the excess weight in employing the heavier boiler is soon balanced by its smaller coal consumption, and a much larger radius of action is obtained by its use. The rectangular form of the Belleville and similar boilers is adapted to the favorable utilization of all the available space, in which respect they are aided by their general design, the boilers being readily widened or narrowed by the addition or omission of elements in order to suit them to the space available.

It appears that for small vessels of high power, where machinery weights must be reduced to the smallest limit, the small-tube type must be used, but where weight is available, and the radius of action of the vessel is of relatively greater importance, the more economical and more durable large-tube type of boiler should be employed. The Appendix shows that this has been the course adopted, battleships and first-class and second-class cruisers being fitted with large-tube boilers, and third-class cruisers and torpedo-boat destroyers with one or other of the small-tube type.

Fitting of Economizers.—As regards the Belleville boiler, an important modification, securing increased economy, has taken place within the period covered by this paper, which may be briefly mentioned. This consists of the adoption of an economizer, or second nest of smaller tubes, placed in the uptake above

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the generator nests, the amount of surface in the latter being reduced at the same time. There is a space between these two nests which forms a combustion chamber, and into which a further supply of air in jets is admitted to re-ignite any unconsumed products of combustion. The feed water passes first through the economizer tubes, entering at the bottom and leaving at the top, whence it is conducted to the generator below. Its temperature being comparatively low, this water is enabled to absorb much heat from the escaping gases, which would otherwise be wasted. All the Belleville boilers in the Royal Navy are of this latter type, except the *Powerful*, *Terrible*, *Sharpshooter* and four cruisers of *Arrogant* class.

In the economizer type 30 per cent. of the tubes in the lower or generator part is omitted, *i. e.*, there are seven pairs of tubes in each element instead of ten. A more scientific arrangement of feed water would be to admit it at the upper part of the economizer, and let it travel downwards, but the arrangement adopted is convenient, and the difference in economy must be trifling. The gain in economy effected by the economizer type, as shown by careful trials made on shore, is at least 12 per cent. to 15 per cent. The best ratio between the surface of the generator and that of the economizer, having regard to the weight of the parts and the comparative efficiency, is not fully determined. Experiments are being made with the lower or generator part, reduced by 40 per cent., *i. e.*, six pairs of tubes high instead of the original ten, the economizer surface being correspondingly increased.

Two other types of boiler, one of the large-tube type and one of intermediate type, have also been fitted for trial in two torpedo gunboats. In the *Seagull* Niclausse boilers are fitted, and although the installation is complete, the vessel has not yet carried out her sea trials. In the boilers of this vessel the outer tubes are 3¼ inches in diameter.

In the *Sheldrake* Babcock-Wilcox boilers have been fitted, and this vessel has carried out all her contract evaporation and sea trials with satisfactory results as regards economy and working of boilers, except that after the sea trials several tubes were found distorted and overheated, and those most bent were replaced.

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This vessel is about to be commissioned for a further series of trials, and her performance thereon, and the lasting qualities of the boiler, will be observed with interest. These boilers have, however, tubes of only $1\frac{13}{16}$ inch diameter, which appears unduly small for ready inspection and cleaning, which would affect their maintenance and durability.

Name of ship and type of boiler.	Duration of trials, hours.	Coal burnt per square foot of grate, pounds per hour.	Equivalent evaporation from and at 212 degrees F.		Ratio of heating surface to grate.	—
			Per square foot of heating surface per hour.	Per pound of coal.		
Seagull, fitted with Niclausse boilers.	8	14.60	4.91	10.77	31.9	Trials on board.
	8	24.20	7.31	9.61	31.9	Trials on board.
Sheldrake, fitted with Babcock and Wilcox boilers.	5	22.50	5.95	12.10	45.7	Trials on shore.
	8	15.00	5.29	12.70	36.1	Trials on board.
	8	25.00	7.68	11.10	36.1	Trials on board.
Sharpshooter, fitted with Belleville boilers without economizers.	8	21.00	7.85	11.05	29.6	Trials on board.
	8	13.10	4.70	10.65	29.6	Trials on board.
	8	9.90	3.53	10.55	29.6	Trials on board.
Belleville boiler with economizer. Average of trials of boilers of many ships.	4	30.13	11.79	11.67	31.3	Trials on shore.

The results of the evaporation trials with these two types of boilers, together with the original Belleville boilers of *Sharpshooter* and the later economizer type of Belleville boiler, are shown in the preceding table, the best hand-picked Welsh coal being used in each case.

Durability of Water-Tube Boilers.—The experience of the last few years enables general conclusions to be arrived at as to the durability and probable life of the water-tube boilers of the large and small-tube types adopted in the Royal Navy. It should be mentioned at first, with regard to the Belleville boiler, which is practically the only variety of large-tube type at present in con-

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TABLE I.—

Name or Class.	Description of Engines.	Number and Type of Boilers.	Diameters and Ratios of Cylinders.	Stroke.	Mean results of Trials.							
					Revolutions per Minute.	Piston Speed.	Steam-Pressure.		I.HP. developed	Duration.	Air-Pressure.	Coal per I.HP. per Hour.
							Boilers.	Engines.				
				Ft. In.		Ft. per Min.				Hrs.	Ins.	Lbs.
8 vessels built under Naval Defence Act.	Vertical inverted tri-compound 3-cylinders	8 cylindrical single-ended	40 ins., 59 ins., 88 ins., 1 : 2·2 : 4·8	4 3	103·1	876	149·0	146·0	11,500	4	0·80	..
					96·8	823	150·0	147·0	9,430	8	0·30	..
Magnificent	"	"	"	4 3	100·3	852	154·0	152·0	12,173	4	2·32[2]	2·22
					96·0	816	150·5	148·0	10,333	8	1·40[2]	2·33
					82·0	697	133·0	131·0	6,116	30	0·42[2]	1·68
Majestic	"	"	"	4 3	107·2	911	147·0	142·0	12,554	4	0·77	2·62
					100·6	855	143·0	137·0	10,453	8	0·22	2 06
					85·5	723	135·0	132·0	6,094	30	Nil	1·83
Renown	"	"	"	4 3	104·0	884	146·0	143·0	12,974	4	0·71	..
					97·8	831	143·0	140·5	10,741	8	0·27	..
					86·8	738	137·0	135·0	6,204	30	Nil	1·88
Victorious	"	"	"	4 3	105·4	895	147·0	144·0	12,203	4	1·25	..
					98·6	838	146·0	144·0	10,300	8	0·26	2·31
					86 8	738	145·0	142·0	6,205	30	Nil	1·60
Prince George	"	"	"	4 3	101·8	865	152·0	147·0	12,280	4	1·21	..
					97·2	826	150·0	145·0	10,465	8	0·44	2·30
					82·9	705	139·0	136·0	6,216	30	Nil	1·80
Jupiter	"	"	"	4 3	102·0	867	150 0	146·0	12,475	4	0 62	..
					94·2	801	148·0	146·0	10.248	8	0·20	..
					81·3	691	146·0	143 0	6,198	30	Nil	1·51
Mars	"	"	"	4 3	104·3	886	146 0	142·0	12,483	4	0·78	..
					98·0	833	150 0	147·0	10,209	8	0·21	..
					83·6	711	139·0	137·0	6,039	30	Nil	1·93
Cæsar	"	"	"	4 3	101·9	866	147·0	142·0	12,694	4	0·78	..
					96·5	820	151·0	144·0	10,692	8	0·27	..
					82·9	705	142·0	140·0	6,328	30	Nil	1·93

[1] Combustion chamber to each pair of furnaces.
[2] Induced draught.

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BATTLESHIPS.

Weights.		Surfaces.		I.HP. per Ton (Mean I.HP.)		Weight in Lbs. per I.HP. (Mean I.HP.)			I.HP. per Square Foot of Grate (Mean I.HP.)	Heating Surface per I.HP. (Mean I.HP.)
Machinery complete.	Boilers complete.	Grate.	Heating.	Machinery complete.	Boilers complete	Engines.	Boilers.	Total.		
Tons.	Tons.	Square Feet.	Square Feet.							
1163	595	731	20,438	10·0 8·1	19·7 15·8	113 146	116 141	227 287	16·0 12·9	1·7 2·1
1357	746	821	25,320	9·0 7·6 4·5	16·3 13·9 8·2	113 132 224	137 162 273	250 294 497	14·8 12·6 7·5	2·1[1] 2·45 4·1
1337	743	821	26,273	9·4 7·8 4·6	16·9 14·1 8·2	106 128 218	133 159 273	239 287 491	15·3 12·7 7·4	2·1[1] 2·5 4·3
1352	726	793	24,840	9·6 7·9 4·6	17·9 14·8 8·5	108 131 226	125 151 262	233 282 488	16·3 13·5 7·8	1·9[1] 2·3 4·0
1354	731	820	25,750	9·0 7·7 4·6	16·7 14·1 8·5	115 135 225	134 159 264	249 294 489	14·9 12·6 7·6	2·1[1] 2·5 4·1
1326	703	820	24,400	9·2 7·9 4·6	17·5 14·9 8·8	114 129 225	128 155 253	242 284 478	15·0 12·8 7·6	2·0[1] 2·3 3·9
1315	704	820	24,944	9·3 7·7 4·7	17·0 14·0 8·8	110 133 221	126 154 254	236 287 475	15·4 12·6 7·6	2·0[1] 2·4 4·0
1328	694	821	24,690	9·4 7·6 4·5	18·0 14·7 8·7	113 139 235	125 152 257	238 291 492	15·2 12·4 7·4	2·0[1] 2·4 4·0
1342	703	821	24,800	9·5 8·0 4·7	18·0 15·2 9·0	113 134 226	124 147 249	237 281 475	15·5 13·0 7·7	1·95[1] 2·3 3·9

[1] Combustion chamber to each furnace.

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TABLE I—

Name or Class.	Description of Engines.	Number and Type of Boilers.	Diameters and Ratios of Cylinders.	Stroke.	Mean results of Trials.							
					Revolutions per Minute.	Piston Speed.	Steam-Pressure.		I.HP. developed	Duration.	Air-Pressure.	Coal per I.HP. per Hour.
							Boilers.	Engines.				
				Ins. Ft. In.		Ft. per Min.				Hrs.	Ins.	Lbs.
Hannibal	Vertical inverted tri-compound 3-cylinders	8 cylindrical single-ended	40 ins., 59 ins., 88 ins.; 1 : 2·2 : 4·8	4 3	103·3	878	148	144	12,176	4	0·67	..
					97·5	829	153	149	10,361	8	0·26	..
					83·7	711	146	141	6,142	30	Nil	1·78
Illustrious	"	"	"	4 3	99·5	846	152	151	12,126	4	1·96[3]	..
					96·5	820	147	145	10,241	8	1 60[3]	..
					83 1	706	142	140	6,155	30	Nil	1·77
Average of battleships after Naval Defence Act	"	"	"	4 3	103·0	875	149	145	12,414	4	0·85	2·40
					97·3	827	148	144	10,404	8	0·27	2·25
					83·8	712	140	138	6,170	30	Nil	1·77
Canopus (6 ships)	"	20 Belleville, with economisers	30 ins., 49 ins., 80 ins.; 1 : 2·7 : 7·1	4 3	108·0[4]	918[4]	300[4]	250[4]	13,500[5]	8	..	..
									10,350[6]	30	..	..
Formidable and Bulwark (6 ships)	"	"	31½ ins., 51½ ins., 84 ins.; 1 : 2·7 : 7·1	4 3	108·0[4]	918[4]	300[4]	250[4]	15,000[4]	8	..	..
									11,500[4]	30	..	..

[1] Combustion chamber to each pair of furnaces.
[4] As specified.
[6] Boilers—generators: fifteen of nine and five of eight elements of seven stages;
[7] Boilers—generators: fifteen of ten and five of nine elements of seven stages;

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BATTLESHIPS—*continued.*

Weights.		Surfaces.		I.HP. per Ton (Mean I.HP.)		Weight in Lbs. per I.HP. (Mean I.HP.)			I.HP. per Square Foot of Grate (Mean I.HP.)	Heating Surface per I.HP. (Mean I.HP.)
Machinery complete.	Boilers complete.	Grate.	Heating.	Machinery complete.	Boilers complete.	Engines.	Boilers.	Total.		
Tons.	Tons.	Square Feet.	Square Feet.							
1,333	721	821	25,320	9·1	16·9	113	132	245	14·8	2·1[1]
				7·8	14·4	132	156	288	12·6	2·4
				4·6	8·5	223	263	486	7·5	4·1
1,338	732	820	25.900	9·1	16·6	112	135	247	14·8	2·1[1]
				7·7	14·0	132	160	292	12·5	2·5
				4·6	8·4	221	266	487	7·5	4·2
1,341	724	817	25,233	9·3	17·1	111	131	242	15·2	2·0
				7·8	14·4	132	156	288	12·7	2·4
				4·6	8·5	225	261	486	7·5	4·1
1,290[4]	623[4]	1,050	33,770	10·5[5]	21·7[5]	111[5]	103[5]	214[5]	12·9[5]	[5]2·5[6]
				8·0[5]	16·6[5]	144[5]	135[5]	279[5]	9·8[5]	[5]3·3[6]
1,400[4]	675[4]	1,170	37,120	10·7[5]	22·2[5]	108[5]	101[5]	209[5]	12·8[5]	[5]2·5[7]
				8·2[5]	17·0[5]	142[5]	131[5]	273[5]	9·8[5]	[5]3·2[7]

[3] Induced draught—omitted from average.
[5] Calculated from specified particulars.
economisers: ten of seven and ten of six elements of ten stages.
economisers: fifteen of eight and five of seven elements of nine stages.

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TABLE II—FIRST-

Name of Ship.	Description of Engines.	Number and Type of Boilers.	Diameters and Ratios of Cylinders.	Stroke.	Mean Results of Trials. Revolutions.	Piston Speed.	Steam Pressure. Boilers.	Steam Pressure. Engines.	I.HP. developed (Mean).	Duration (Hours)	Air-Pressure.	Coal per I.HP. per Hour.
				Ft In		Ft. per Min.						Lbs.
Edgar Class	Vertical triple-expansion 3-cylinder	See Foot-note (1)	40 ins., 59 ins., 88 ins. 1 : 2·17 : 4·84	4 3	99·1	842·3	150·0	146·6	10,517	8	0·2	1·70
					102·7	923·0	146·2	143·0	12,851	4	0·7	..
											Vacuum in Smoke Boxes.	
Powerful	Vertical triple-expansion 4-cylinder 4-crank	48 of Belleville type, without economizers	45 ins., 70 ins., 2 of 76 ins. 1 : 2·4 : 5·7	4 0	67·2	537·6	225·0	180·0	5,044	30	0·30	2·06
					102·8	822·4	232·0	196·0	18,459	30	0·41	1·83
					109·6	876·8	237·0	197·0	22,725	4	0·34	1·92
					114·4	915·2	257·0	207·0	25,900	4	0·33	2·02
Terrible	"	"	"	1 0	64·4	515·2	208·0	162·0	5,073	30	0·20	[2]
					64·0[3]	512·0[3]	217·0[3]	..	5,084[3]	60[3]	..	2·3[3]
					102·7	821·6	223·0	199·0	18,500	30	0·31	1·71
					108·8	870·4	225·0	196·0	22,370	4	0·34	2·00
					112·0	896·0	229·0	197·0	25,648	4	0·32	2·20
	Average for 30 hours at		5,000 I.HP.		65·8	526·4	216·5	171·0	5,058	30	0·25	2·18
	"	30 "	18,000 I.HP.		102·75	822·0	227·5	197·5	18,479	30	0·36	1·77
	"	4 "	22,000 I.HP.		109·2	873·6	231·0	196·5	22,547	4	0·34	1·96
	"	4 "	full power .		113·2	905·6	243·0	202·0	25,774	4	0·325	2·11
Andromeda	Vertical triple-expansion 4-cylinder 4-crank	30 of Belleville type, fitted with economizers	34 ins., 55½ ins., 2 of 64 ins. 1 : 2·66 : 7·08	4 0	69·2	553·6	197·0	162·0	3,388	30	0·25	1·98
					107·1	856·8	266·0	215·0	12,621	30	0·30	1·74
					117·5	940·0	286·0	230·0	16,751	8	0·30	1·76
Diadem	"	"	"	4 0	67·2	537·6	265·0	202·0	3,318	30	0·24	2·21
					107·6	860·8	280·0	245·0	12,813	30	0·35	1·61
					119·1	952·8	291·0	249·0	17,262	8	0·45	1·76
Europa	"	"	"	4 0	65·4	523·2	212·0	132·0	3,302	30	0·25	2·24
					103·8	830·4	265·0	239·0	12,739	30	0·30	1·94
					112·5	900·0	279·0	232·0	17,010	8	0·32	..
Niobe	"	"	"	4 0	70·1	560·8	200·0	146·0	3,348	30	0·28	1·76
					107·5	860·0	258·0	220·0	12,968	30	0·20	1·55
					117·5	940·0	290·0	236·0	16,822	8	0·15	1·66
	Average for 30 hours at		3,300 HP. .		67·9	543·8	218·5	160·5	3,339	30	0·255	2·04
	"	30 "	12,500 HP. .		106·5	852·0	267·0	230·0	12,785	30	0·287	1·71
	"	8 "	full power .		116·6	933·2	286·5	236·7	16,961	8	0·305	1·73

[1] Five ships have four double-ended return-tube and one single-ended boiler; four ships have
[2] Coal consumption, on this trial high, due to irregular stoking and some mechanical defects

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CLASS CRUISERS.

Weights.		Surfaces.		I.HP. per Ton (Mean I.HP.)		Weight in Lbs. per I.HP. (Mean I.HP.)			I.HP. per Square Foot of Grate (Mean I.HP.).	Heating Surface per I.HP. (Mean I.HP.).
Machinery complete.	Boilers complete.	Grate.	Heating.	Machinery.	Boilers.	Engines.	Boilers.	Total.		
		Square Feet.	Square Feet.							
1,161	646	812	24,908	9·0	16·2	111	138	249	12·9	2·3
1,161	646	812	24,908	11·1	20·1	91	111	202	15·2	1·9
2,235	1,164	..	..	..	..	..	..	..	..	..
		2,200	67,800	8·26	15·85	130	141	271	8·39	3·67
		2,200	67,800	10·16	19·51	106	115	221	10·33	2·98
		2,200	67,800	11·58	22·24	93	101	194	11·77	2·61
2,225	1,148	..	..	..	..	..	..	..	..	..
		2,200	67,800	8·31	16·10	131	139	270	8·40	3·66
		2,200	67,800	10·05	19·48	108	115	223	10·16	3·03
		2,200	67,800	11·52	22·33	95	100	195	11·65	2·64
2,230	1,156	..	..	..	..	..	..	..	..	..
		2,200	67,800	8·29	16·00	130	140	270	8·39	3·66
		2,200	67,800	10·10	19·49	107	115	222	10·24	3·00
		2,200	67,800	11·55	22·28	94	100	194	11·71	2·63
1,515	765	..	..	..	..	..	..	..	..	..
		1,450	42,270	8·33	16·50	133	136	269	8·70	3·34
		1,450	42,270	11·05	21·90	101	102	203	11·55	2·52
1,512	748	..	..	..	..	..	..	..	..	..
		1,483	40,550	8·47	17·12	134	131	265	8·64	3·16
		1,483	40,550	11·41	23·06	100	97	197	11·63	2·34
1,564	782	..	..	..	..	..	..	..	..	..
		1,469	40,604	8·14	16·27	138	138	276	8·67	3·18
		1,469	40,604	10·87	21·73	103	103	206	11·57	2·38
1,568	773	..	..	..	..	..	..	..	..	..
		1,441	40,538	8·27	16·76	137	134	271	8·99	3·12
		1,441	40,538	10·73	21·74	106	103	209	11·66	2·41
1,540	767	..	..	..	..	..	..	..	..	..
		1,460	40,990	8·30	16·66	135	135	270	8·75	3·20
		1,460	40,990	11·01	22·11	103	101	204	11·60	2·41

eight single-ended return-tube boilers.
which were afterwards made good.

[3] Trial made at sea.

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TABLE III.—SECOND

Name of Ship.	Description of Engines.	Number and Type of Boilers.	Diameters and Ratios of Cylinders.	Stroke.	Mean results of Trials. Revolutions.	Piston Speed.	Steam Pressure. Boilers.	Steam Pressure. Engines.	I.H.P. developed (Mean).	Duration.	Air Pressure.	Coal per I.H.P. per Hour.
				Ft. In.		Ft. per Min.				Hrs.	Ins.	Lbs.
Apollo and Astræa classes	Vertical 3-cylinder triple-expansion	See footnote (1)	See footnote (2)	3 3	130·8	850 2	145·0	141·0	7423 0	8	0·3	..
					140·0	910 0	147·0	142·5	9271·0	4	1·0	..
Diana	Twin-screw vertical 3-cylinder triple-expansion	8 3-furnace cylindrical, single-ended, return-tube	33 ins., 49 ins., 74 ins.; 1 : 2·2 : 5·0	3 3	146 0	949·0	149·0	146 0	9875·0	4	1·29	..
					136·3	885·9	145·0	142·0	8252·0	8	0·46	2·25
					116·1	754·6	142·0	139·0	4916·0	30	..	1·47
Dido	"	"	"	3 3	144·1	936 6	150·0	146·0	9863·0	4	0·75	..
					136·4	886 6	150·0	145 0	8339 0	8	0·19	1·98
					117·2	761·8	147·0	145·0	4925·0	30	..	1·60
Doris	"	"	"	3 3	148·5	965·2	154·0	150·0	9878 0	4	1 2	..
					139·8	908 7	152·0	150·0	8425·0	8	0·45	..
					118·7	771·5	143·0	140·0	4933·0	30	..	1·47
Eclipse	"	"	"	3 3	141·7	921·0	155·0	149 0	9870·0	4	0·94	..
					134·7	875·5	152·0	148·0	8236·0	8	0·39	2·26
					116 0	754·0	135·0	129 0	4855·0	30	..	1·87
Isis	"	"	"	3 3	144·9	941·8	151·0	148·0	9840·0	4	1·05	..
					136·1	884·6	149 0	147·0	8208·0	8	0·41	2·20
					117 8	765·7	145·0	143·0	4925·0	30	..	1·60
Juno	"	"	"	3 3	149·3	970·4	154·0	151·0	9808·0	4	0·92	..
					138·5	900·2	153·0	151·0	8317·0	8	0·42	..
					118·4	769·6	142·0	139·0	4857·0	30	..	1·64
Minerva	"	"	"	3 3	137·6	894·4	152·0	149·0	9902·0	4	1·02	..
					127·9	831·3	151·0	149·0	8216·0	8	0·27	2·10
					111·6	725·4	146·0	144·0	4919·0	30	..	1·71
Talbot	"	"	"	3 3	139·5	906·7	149·0	144·0	9841·0	4	1 06	..
					132·0	858·0	147·0	142·0	8569 0	8	0·41	..
					114·2	742·3	132·0	130·0	4904·0	30	..	1·84
Venus	"	"	"	3 3	146·1	949·6	145·0	143·0	9744·0	4	1·34	..
					136·9	889·8	153·0	150·0	8204·0	8	0·45	2·28
					118·0	767·0	148·0	146·0	4876·0	30	..	1·60
	Average for forced draught				144·2	937·3	151·0	147·0	9846·7	4	1·06	..
	" natural draught				135·4	880·1	150·0	147·0	8307·3	8	0·38	2·18[3]
	" 30 hours' coal consumption				116·4	756·6	142·0	139·0	4901·0	30	Nil	1·64

[1] Twenty-one vessels have three double-ended and two single-ended boilers, and eight vessels
[2] Nineteen vessels have cylinders 33½ inches, 49 inches and 74 inches; ratios, 1 : 2·18 : 4·88.
[3] Average of six ships.

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CLASS CRUISERS.

Weights.		Surfaces.		I.HP. per Ton (Mean I.HP.).		Weight in Lbs. per I.HP. (Mean I.HP.).			I.HP. per Square Foot of Grate (Mean I.HP.).	Heating Surface per I.HP. (Mean I.HP.).
Machinery complete.	Boilers complete.	Grate.	Heating.	Machinery complete.	Boilers complete.	Engines.	Boilers.	Total.		
		Square Feet.	Square Feet.							
748	434·4	575·0	15,641	9·92	17·0	94	132	226	12·9	2·1
748	434·4	575·0	15,641	12·40	21·3	76	105	181	16·1	1·7
897	545·0	619·5	18,484	10·99	18·12	81	123	204	15·94	1·87
				9·19	15·14	96	148	244	13·32	2·24
				5·48	9·03	161	248	409	7·94	3·75
912	550·0	626·0	18,652	10·81	17·92	82	125	207	15·75	1·89
				9·14	15·15	97	148	245	13·32	2·23
				5·40	8·95	165	250	415	7·86	3·78
906	544·0	594·0	18,440	10·90	18·15	83	123	206	16·61	1·86
				9·29	15·48	96	145	241	14·18	2·18
				5·44	9·06	165	247	412	8·30	3·73
921	548·0	637·0	18,667	10·71	18·00	85	124	209	15·49	1·89
				8·94	15·02	102	149	251	12·92	2·26
				5·27	8·86	172	253	425	7·62	3·84
911	550·0	626·0	18,652	10·80	17·90	82	125	207	15·71	1·89
				9·01	14·93	99	150	249	13·11	2·27
				5·41	8·97	165	250	415	7·86	3·78
906	544·0	594·0	18,440	10·82	18·02	83	124	207	16·51	1·88
				9·17	15·28	98	146	244	14·00	2·21
				5·36	8·92	166	252	418	8·17	3·79
938	558·0	649·2	18,696	10·55	17·75	86	126	212	15·25	1·88
				8·76	14·73	104	152	256	12·65	2·27
				5·25	8·83	173	254	427	7·58	3·80
940	543·0	646·0	18,696	10·46	18·12	91	123	214	15·23	1·89
				9·11	15·78	104	142	246	13·26	2·18
				5·21	9·04	182	248	430	7·59	3·81
904	549·0	623·0	18,484	10·78	17·74	82	126	208	15·64	1·89
				9·07	14·94	97	150	247	13·16	2·25
				5·39	8·88	164	252	416	7·82	3·79
915	548·0	623·8	185·79	10·76	17·97	84	124	208	15·79	1·88
..	..	..	..	9·07	15·16	99	148	247	13·32	2·23
..	..	..	..	5·35	8·95	168	250	419	7·86	3·78

have eight single-ended return-tube boilers.
The remainder have cylinders 33 inches, 49 inches and 74 inches; ratios, 1 : 2·25 : 5·03.

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TABLE IV—THIRD-

Name of Ship.	Description of Engines.	No. and Type of Boiler.	Diameters and Ratios of Cylinders.	Stroke.	Mean Results of Trials. Revolutions.	Piston Speed.	Steam-Pressure. Boilers.	Steam-Pressure. Engines.	I.HP. Developed (Mean).	Duration.	Air-Pressure.	Coal per I.HP. per Hour.
				Ft. in.		Ft. per Min.				Hrs.	Ins.	Lbs.
"Pearl" Class	Vertical 3-cylinder triple-expansion	4, double-ended; 4, furnace.	30½ ins., 45 ins., 68 ins. 1 : 2 17 : 4·97	2 9	141·0	775·5	151	146	5,016	8	0·2	..
					160·0	880·0	151	146	7,469	4	1·4	..
Pactolus.	Vertical 3-cylinder triple-expansion	8 Blechynden	20½ ins., 33 ins., 54 ins. 1 : 2·59 : 6·93	2 3	172 8	777·6	224	206	3,631	30	1·18	2·46
					197·7	889·6	257	248	5,428	8	1 11	not taken
					213·8	962·1	253	247	7,201	4	3·3	
Pegasus.	"	8 Reed	"	2 3	176·4	793 8	261	237	3,698	30	0·4	1·96
					203·2	914·4	278	239	5,400	8	0 86	not taken
					217·7	979·6	255	220	7,127	4	2·44	
Pelorus.	"	8 Normand	"	2 3	162·1	729·4	249	197	3,559	30	0 78	2·20
					188·8	849·6	252	200	5,379	8	1·7	..
					217·2	977·4	260	223	7,094	4	4·3	..
Perseus[1]	"	8 Thornycroft	"	2 3	174·1	783·4	224	211	3,627	30	0 30	2·1
					195·8	881·1	251	231	5,243	8	1·1	2·26
					220 0[2]	990 0[2]	300[2]	250[2]	7,000[2]	4[2]	..	..
Pomone[6]	"	8 Blechynden	"	2 3	175·6	709·2	247	244	3,600	30	0·87	2·45
					200·9	904·0	225	219	5,541	8	1·40	not taken
					220·3	991·6	252	243	7,340	4	2·77	
Proserpine	"	8 Thornycroft	"	2 3	168·7	759·1	232	210	3,644	30	0 53	2·40
					194·2	873·9	257	243	5,336	8	0 94	2 47
					221·6	997·2	260	247	7,145	4	2 9	3·16
Prometheus[4]	"	"	"	2 3	..	..	..	..	3,500[5]	30[5]	..	..
					..	..	..	..	5,000[5]	8[5]	..	..
					220·0[5]	990·0[5]	300[5]	250[5]	7,000[5]	4[5]	..	..
Psyche[6]	"	"	"	2 3	170·7	768·4	215	215	3,637	30	0·40	2·31
					..	..	..	..	5,095	8	..	2·44
					217·8	980·1	240	235	7,006	4	3·7	..
Pyramus[4]	"	8 Reed	"	2 3	..	..	..	..	3,500[5]	30[5]	..	..
					..	..	..	..	5,000[5]	8[5]	..	..
					220·0[5]	990·0[5]	300[5]	250[5]	7,000[5]	4[5]	..	..
	Average for 30 hours at 3,500 HP.[7] .				171·5	771·7	236	217	3,628	30	0·64	2·27
	" " 8 " 5,000 HP. .				196·8[8]	885 4[8]	253[8]	230[8]	5,388[8]	8[8]	1·18[8]	2·36[8]
	" " 4 " full power[9] .				218·1	981·3	253	236	7,152	4	3·23	..

[1] Full-power trial has not yet taken place.
[2] Particulars for full power are from specification.
[3] Calculated from specified I.HP. [4] Vessel not yet tried. [5] Particulars are from specification.

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CLASS CRUISERS.

Weights.		Surfaces.		I.HP. per Ton (Mean I.HP.)		Weight in Lbs. per I.HP. (Mean I.HP.)			I.HP. per Square Foot of Grate (Mean I.HP.).	Heating Surface per I.HP. (Mean I.HP.).
Machinery Complete.	Boilers Complete.	Grate.	Heating.	Machinery.	Boilers.	Engines.	Boilers.	Total.		
		Square Feet.	Square Feet.							
539	314	410·0	11,025	9·3	16·0	100·0	140·0	240	12·2	2·1
539	314	410·0	11,025	13·6	23·8	68 0	94·0	162	18·2	1·47
383	188	349·7	17,504	9·48	19·41	121·0	115·0	236	10·41	4·82
..	..	..	..	14·15	28·91	82·5	75·5	158	15·52	3·22
..	..	..	..	18·78	38·36	60·5	58·5	119	20·59	2·43
378	185	360·0	18,876	9·78	19·98	117·0	112·0	229	10·27	5·10
..	..	..	..	14·28	29·15	80·0	77·0	157	15·00	3·49
..	..	..	..	18·85	38·48	61·0	58·0	119	19·79	2·64
382	169	350·0	15,856	9·34	21·06	134·0	106·0	240	10·16	4 45
..	..	..	..	14·08	31·79	88·5	70·5	159	15·37	2·94
..	..	..	..	18·58	41·92	66·5	53·5	120	20·26	2·23
365	165	353·0	17,760	9·93	21·98	123·0	102·0	225	10·27	4 89
..	..	..	..	14·36	31·77	85·5	70·5	156	14·85	3·38
..	..	..	..	19·17 [3]	42·42 [3]	64·0 [3]	53·0 [3]	117 [3]	19·83 [3]	2·54 [3]
360 [5]	170 [5]	350·0	17,504	10·00 [6]	21·19 [6]	118·0 [6]	106·0 [6]	224 [6]	10·29	4·87
..	..	..	..	15·40 [6]	32·60 [6]	76·0 [6]	69·0 [6]	145 [6]	15·80	3·17
..	..	..	..	20·40 [6]	43·15 [6]	58·0 [6]	52·0 [6]	110 [6]	20·97	2·39
409	172	348·75	20,508	8·90	21·18	147·0	105·0	252	10·47	5·62
..	..	..	..	13·03	31·04	100·0	72·0	172	15·30	3·84
..	..	.	..	17·44	41·56	74·5	53·5	128	20·48	2·87
360 [5]	156 [5]	353·0	17,760	9·72 [6]	22·43 [6]	120·0 [6]	100·0 [6]	230 [6]	9·91	5·07
..	..	..	..	13·88 [6]	32·05 [6]	91·0 [6]	70·0 [6]	161 [6]	14·16	3·55
..	..	..	..	19·44 [6]	44·87 [6]	65·0 [6]	50·0 [6]	115 [6]	19·83	2·54
360 [5]	165 [5]	350·0	20,508	10·10 [6]	22·00 [6]	120·0 [6]	102·0 [6]	222 [6]	10·40	5·64
..	..	..	..	14·15 [6]	30·90 [6]	85·0 [6]	73·0 [6]	158 [6]	14·55	4·02
..	..	..	..	19·46 [6]	42·46 [6]	62·0 [6]	53·0 [6]	115 [6]	20·01	2·93
360 [5]	159 [5]	360·0	18,876	9·72 [6]	22·01 [6]	128·0 [6]	102·0 [6]	230 [6]	9·72	5·39
..	..	..	..	13·88 [6]	31·44 [6]	89·0 [6]	72·0 [6]	161 [6]	13 90	3·77
..	..	..	..	19·44 [6]	44·02 [6]	64·0 [6]	51·0 [6]	115 [6]	19·44	2·69
383	176	352·3	18,100	9·65	20·95	126·0	107·0	233	10·32	5·06
383	176	..	..	14·21 [7]	30·88 [7]	85·4 [7]	72·6 [7]	158 [7]	15·20 [7]	3·44 [7]
388	178	..	..	18·92	40·99	63·5	54·5	118	20·35	2·58

[6] Calculated from specified particulars.
[5] Average for six ships. Coal per I.HP. for three ships only.
[7] Average for seven ships.
[9] Average for six ships.
* Mean results of Pomone's and Psyche's trials are based on preliminary reports only.

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TABLE V—TORPEDO-

Name or Class and Number of Ships.	Description of Engines.	Number and Type of Boilers.	Diameters and Ratios of Cylinders.	Stroke.	Mean Results of Trials. Revolutions per Minute.	Piston Speed.	Steam-Pressure. Boilers.	Steam-Pressure. Engines.	I.HP.	Duration.	Air-Pressure.	Coal per I.HP. per Hour.	Speed.
				Ins.		Ft. per Min.				Hrs.	Ins.	Lbs.	Knots.
Daring, 2	4-cylinder triple-expansion	Thornycroft's water-tube 3 No.	19 ins., 27 ins., 2 of 27 ins 1:2·019: 4·03	16	371·4 127·9	990·4 341·0	196 195	193 192	4208·9 221·0	3 8	3·37 nil	.. 2·66	27·7 9·9
Havock, 1	3-cylinder triple-expansion	Locomotive 2 No.	18 ins., 26 ins., 39½ ins. 1:2·08: 4·81	18	359·3 139·3	1077·9 417·8	160 114	155 105	3497·0 212·0	3 8	3·66 nil	.. 2·56	26·07 10·78
Hornet, 1	"	Yarrow's water-tube 8 No	"	18	392·6	1177·8	169	161	3884·0	3	1·6	2·4	27·6
Ferret, 2	"	Normand's water-tube 4 No.	19 ins., 29 ins., 43 ins. 1:2·32: 5·12	18	306·0 127·5	1098·0 382·5	171 103	.. ..	4484·0 258·0	3 8	4·1 nil	.. 2·3	27·25 10·83
Ardent, 3	4-cylinder triple-expansion	Thornycroft's water-tube 3 No.	19 ins., 27 ins., 2 of 27 ins. 1:2·019: 4·03	16	392·3 169·7	1046·1 452·5	204 180	200 180	4368·6 499·0	3 12	2·87 nil	3·49 1·53	28·35 13·0
Charger, 3	3-cylinder triple-expansion	Locomotive 2 No.	18 ins, 26 ins., 39½ ins. 1:2·08: 4·81	18	365·0 169·1	1095·0 507·4	161 132	157 ..	3158·0 398·0	3 12	2·54 0 to 0·25	2·59 2·17	26·11 12·93
Dasher	"	Thornycroft's water-tube 4 No.	"	18	372·0 175·0	1116·0 525·0	204 170	182 167	3922·8 414·9	3 8½	2·8 0·18	.. 2·48	.. 13·05
Janus, 3	"	Reed's water-tube 4 No.	18 ins., 27½ ins., 42 ins. 1:2·33: 5·44	18	365·6 153·7	1096·8 461·1	194 110	174 ..	3885·0 341·4	3 10	2·39 0 to 0·47	3·15 2·55	27·88 12·77

(*a*) To be re-boilered with Yarrow's water-tube type.
(*b*) Of the three vessels of Charger class Dasher has been re-boilered with Thornycroft's

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BOAT DESTROYERS.

Weights.		Surfaces.		I.HP. per Ton (Mean I.HP.).		Weight in Lbs. per I.HP. (Mean I.HP.).			I.HP. per Square Foot of Grate (Mean Power).	Heating Surface per I.HP. (Mean Power).	Load on Safety Valves per Square Inch.
Machinery complete.	Boilers complete.	Grate.	Heating.	Machinery complete.	Boilers complete.	Engines.	Boilers.	Total.			
Tons.	Tons.	Square Feet.	Square Feet.								Lbs.
108·2	56·0	189·0	8,892	38·8	75·0	28	30	58	22·2	2·11	210
..	..	..	..	..	..	..	..	..	..	..	..
94·0	58·0	100·0	4,656	37·2	60·0	23	37	60	34·97	1·33	180 (*a*)
..	..	..	..	..	..	..	..	..	..	..	..
90·6	49·0	154·4	8,216	42·8	79·1	24	28	52	25·1	2·11	180
123·2	64·2	149·8	8,800	36·3	69·7	30	32	62	29·9	1·96	175
..	..	..	..	..	..	..	..	..	..	..	..
108·2	56·0	189·0	9,780	40·3	77·8	27	29	56	23·1	2·23	210
..	..	..	..	..	..	..	..	..	..	..	..
101·7	63·0	100·0	4,732	31·0	50·0	27	45	72	31·58	1·49	180 (*b*)
..	..	..	..	..	..	..	..	..	..	..	..
99·9	59·3	173·3	8,508	39·2	66·0	23	34	57	22·6	2·16	230 (*c*)
..	..	..	..	..	..	..	..	..	..	..	..
116·2	70·6	209·24	10,164	33·4	54·9	26	41	67	18·5	2·61	210
..	..	..	..	..	..	..	..	..	..	..	..

water-tube type and tried with results as at (*c*). Load on safety-valves 230 lbs per square inch, reduced at engines to 180 lbs. The Charger and Hasty are also to be re-boilered with similar boilers.

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TABLE

—	Steam-Pressure. Boilers / Engines.	I.HP. (a) Full Power, F. D. (b) Full Power N. D. (c) Continuous.	Floor Space. Engine Room. Length.	Engine Room. Mean Width.	Engine Room. Square Feet per I.HP.	Boiler Rooms. Length × Mean Width.	Boiler Rooms. Square Feet per I.HP.	Total Square Feet per I.HP.
1	2	3	4		5	6	7	8
			Feet.	Feet.		Feet.	Feet.	
A Majestic[1]	155/150	(a) 12,000 (b) 10,000 (c) 6,000	43·5	46·0	(b) 0·200	79·5 × 45·5	(b) 0·362	(b) 0·562
A Venus	155/150	(a) 9,600 (b) 8,000 (c) 4,800	48·0	33·5	(b) 0·200	91·0 × 33·8	(b) 0·385	(b) 0·585
A Royal Sovereign[1]	155/150	(a) 13,000 and 11,000 (b) 9,000 (c) 5,400	44·0	40·0	(b) 0·196	76·0 × 40·0	(b) 0·340	(b) 0·536
A Crescent	155/150	(a) 12,000 (b) 10,000 (c) 6,000	40·0	46·0	(b) 0·184	93·5 × 37·0	(b) 0·345	(b) 0·530
B Powerful[2]	260/210	(a) .. (b) 25.000 (c) 18,000	60·0 × 42·0 18·0 × 28·0 for auxiliary machinery.		(b) 0·103 0·02[2] 0·123	112·0 × 42·0 74·0 × 34·0	(b) 0·290	(b) 0·413
B Arrogant	300/250	(a) .. (b) 10,000 (c) 7,000	48·0	35·5	(b) 0·171	101·0 × 31·0	(b) 0·313	(b) 0·484
C Pelorus	300/250	(a) 7,600 (b) 5,000 (c) 3,500	37·8	34·0	(b) 0·257	80·0 × 24·0	(b) 0·384	(b) 0·640
D Diadem	300/250	(a) .. (b) 16.500 (c) 12,500	55·5	43·5	(b) 0·147	66·0 × 36·0 66·0 × 40 0	(b) 0·305	(b) 0·452
D Argonaut	300/250	(a) .. (b) 18,000 (c) 13,500	55·0	43·0	(b) 0·132	66·0 × 39·0 65·0 × 34 5	(b) 0·267	(b) 0·400
D Canopus[1]	300/250	(a) .. (b) 13,500 (c) 10,250	44·0	46·0	(b) 0·150	84·0 × 43·25	(b) 0·270	(b) 0·420

[1] Separate auxiliary machinery room.

[2] Evaporator and dynamo

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VI.

Weight of Machinery (Main) excluding Auxiliaries and Propellers, &c.					Piston Speed.	Stroke.	Revolutions.
Engine Room.	Boiler Rooms.	Per I.HP.		Total per I.HP.			
		Engine Room.	Boiler Rooms.				
9	10	11	12	13	14	15	16
Tons.	Tons.	Lbs.	Lbs.	Lbs.	Feet per Minute.	Inches.	Per Minute.
443	721	88	161	(b) 259	850	51	100
278	547	78	153	(b) 231	910	39	140
397	595	99	148	(b) 247	918	51	108
365	644	82	144	(b) 226	850	51	100
799	1156	72	104	(b) 176	880	48	110
288	462	65	103	(b) 168	910	39	140
164	175	74	79	153	990	27	220
580	766	79	104	(b) 183	880	48	110
592	794	74	99	(b) 173	960	48	120
440[4]	626[4]	73[4]	104[4]	177[4]	918[4]	51	108

not stowed in engine room. [3] Auxiliary. [4] Estimated.

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siderable use, that in the generator portion the pairs of tubes next the fire are $\frac{3}{8}$ inch and the pairs next above $\frac{5}{16}$ inch thick, while the upper and more numerous tubes are 0.192 inch thick. In the small-tube type, however, the thickness in most cases is 0.104 inch, but has been recently increased to 0.128 inch in the rows next the fire and 0.116 inch in the others. The ratio of the thicknesses, *i. e.*, $\frac{192}{116}$, is probably a rough approximation to the comparative durability of the tubes in the absence of special causes of corrosion. In the Belleville boiler experience has shown that the life of the boiler tubes will not be less than two commissions. Occasionally tubes are met with in which local pitting proceeds rapidly and causes early failure, while if by shortness of water or accumulation of salt or grease overheating and burning occur, the failure of particular tubes will be rapid. As a general rule, however, the life of the tubes will probably not be less than above stated.

As regards the small-tube boiler, of which so many are fitted in torpedo-boat destroyers and the smaller cruisers, experience shows that the conditions are not so favorable. The hard forcing to which they are subject, the difficulty of thoroughly cleaning them, and their comparative thinness, etc., renders their life under present conditions of preservation and service much shorter.

Corrosion.—Zinc slabs in all varieties of water-tube boilers still prove themselves effective in arresting much corrosion that would otherwise take place, the slabs being acted on freely when fresh water and even distilled water only is used for make up. Attention to them and improvement of the details of attachment so as to secure more effective contact, has arrested many cases of corrosion. Owing to the construction of water-tube boilers, the preservative effects of zinc cannot be realized to the same extent as in the water-tank boilers, and much of the tube surface in the former boilers must from the nature of the case be more or less remote from the sphere of preservative action of the zinc slabs, even when they are distributed in the best practicable manner.

The parts of the boiler adjacent to the feed-water inlet are particularly liable to corrosion, especially if the fittings be such that the feed water is directed on to a small area. This corrosion

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appears to be due to the air and other gases liberated from the feed water when heated attaching themselves to the adjacent parts of the boiler and causing decay. Corrosion of this nature is apparently not arrested by increasing the zinc protection, and requires special treatment according to the circumstances of the case. The general distribution of the feed amongst a considerable quantity of water before it reaches the temperature of the surrounding water largely prevents local action in water-tank boilers; but in the water-tube boilers, as the feed-water is generally discharged in a small chamber containing a limited quantity of water, its temperature is rapidly raised with only a small surface from which the liberated gases can escape, and the tendency to concentrated local action on the adjoining plates and tubes is proportionately increased. The advantage of using distilled water is obvious, as it contains much less air and dissolved gases than the ordinary fresh water obtained from shore. In the case of the small-tube boilers distilled water has another advantage in its freedom from lime salts which are contained in much fresh water obtained from the shore; the frequent use of shore water of this character has been found to produce lime deposits in the tube, which obstruct the circulation, retard the passage of heat and shorten the life of the tube. Several cases have occurred in which the corrosion has been attributed to the use of considerable quantities of shore water with restricted arrangements for getting rid of air.

In the economizer type of Belleville boiler the feed water, with its air and impurities, is first discharged through the economizer tubes, and to minimize corrosion due to this cause the interiors of the economizer tubes are coated with a wash of lime. In the later examples the economizer tubes are galvanized on the inside and outside to prevent corrosion. As the temperature of the water inside them, as well as the gases outside, is moderate, the objections to internal galvanizing which apply to the lower or generator portion do not hold in the case of the economizer tubes.

A number of cases have occurred with water-tube boilers, especially of the small-tube types, of damage through the bursting

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of tubes. Omitting cases where the tubes were of copper, and the special case of the *Ariel*, where a fatal accident occurred owing to a tube being improperly secured in the tube plate, none of these have been attended with injury to any person or to any part of the vessel except the tubes of the boiler; and, speaking generally, their cause is attributable to overheating of tube caused by impeded circulation due to obstruction or dirt in the tube.

To prevent these failures the practice of carefully searching all the tubes periodically with a brush or other solid instrument has been established. A careful examination of the boilers of vessels in which such failures occurred revealed in some instances tubes in which there was a slight increase of diameter at a particular part, and it has been noticed by observation of such cases that the tube has ultimately failed by bursting or splitting. This has suggested the further precaution of a careful examination of all accessible tubes by gaging them on the outside and then cleaning them internally, and in some cases renewing at once any that show signs of increase of diameter. It is anticipated that with these precautions bursting of boiler tubes will become rare, as with the precautions mentioned they recently have been less frequent.

Influence of Steam Pressure on Weight and Space.—The preceding tables show that a considerably increased steam pressure has been used in recent warships, and it was predicted that troubles of various kinds would in consequence be met with which would be difficult to overcome, and which would seriously impair the efficiency of the machinery. Such experience has now been obtained with a boiler pressure of 300 pounds per square inch, and an engine pressure of 250 pounds, and it can be said that no difficulty has been experienced; and the maintenance of the high-pressure machinery in efficient condition is hardly more difficult than with the 150 pounds per square inch prevalent for so many years. The objects aimed at in making these considerable advances in steam pressure were to secure reduction in the weight and space occupied by the propelling machinery, and further to improve the economy of the engines

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of very high powers when working at low powers by enabling such powers to be developed in a smaller engine.

As regards weight and space, Table No. VI clearly shows the results. The group of vessels of various classes marked A have all water-tank boilers, and steam pressure of 155 pounds and 150 pounds per square inch at the boilers and engines respectively. Those of group B have Belleville boilers without economizers, but with higher steam pressures. Group C represents the third-class cruisers with water-tube boilers of small-tube type and high steam pressure, while group D represents the most modern arrangement for large ships having Belleville boilers with economizers. Omitting C from the comparison, as it is of special type, it will be seen by comparing the figures in columns 5, 7 and 8 that a substantial reduction has taken place in the space occupied, while column 13 shows a similar reduction in weight. It is not advanced that the comparative figures given in this table are more than approximate, but as regards weight and space they indicate sufficiently the results attained.

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THE ENDURANCE OF THE ORDINARY COPPER ALLOYS IN SEA WATER.

By Torpedo-Chief Engineer Diegel. Translated by Emil Theiss, U. S. Navy.

[Abstract of an article on the above subject contained in the November issue of "Marine-Rundschau."]

I. ALLOYS IN GENERAL AND ENDURANCE OF COPPER ALLOYS.

The word "alloy" is generally used to designate the combination of two or more metals or of metals and metalloids. The word, however, gives no indication of the nature of an alloy, nor has its true nature been scientifically established. Many maintain that an alloy is a mixture formed by the fusion of several metals, others regard it as a solution of metals in one another, or of metalloids in metals; for example, zinc or tin dissolved in copper, carbon in iron, etc. Others are of the opinion that an alloy must be considered as the solution of one or more chemical combinations in metals. It is assumed in the latter case that the chemical combinations, proceeding according to certain weight ratios in accordance with the atomic weights, are formed and dissolved in the surplus metal. Chemists, however, make an exception in the case of brass, which they consider simply as a mechanical mixture of copper and zinc.

An argument in favor of the theory that alloys are usually solutions of the metals one in the other, or of metalloids in metals, and not simply mechanical mixtures, is furnished by the intimate association of the constituents. The different metals or metalloids of an alloy cannot be detected by the human eye under any microscope, and can be separated only in a chemical way. In addition, the qualities of the alloy as to temperature of fusion, specific weight, hardness, toughness, etc., are not immediately referable to their constituents, which ought to be the case with

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a mechanical mixture. For example, copper and tin may produce a very hard bronze, while both metals separately are very soft.

The fact that two metals are alloyed the more readily the more dissimilar they are chemically, may be taken to show that they combine according to the laws of chemistry. Also the fact that a number of alloys do not segregate when poured, whenever their combination is in accordance with their atomic weights, while they will segregate when these weights differ. Examples of non-segregating alloys are: 61.8 parts by weight of copper and 38.2 parts of tin (corresponding with the chemical formula $Sn\ Cu_3$); 68.3 parts of copper with 31.7 parts of tin (formula, $Sn\ Cu_4$).

The formation of a chemical compound is further evidenced in the case of some alloys (for example, zinc with copper, lead with bismuth, aluminum with copper) by the production of heat when alloyed. In the latter case the heat produced is so great that it cannot be ascribed entirely to the reduction of the suboxide of copper. Probably, however, only a limited amount of the aluminum enters into chemical combination with the copper. In the case of copper-zinc alloys, also, it is believed that the copper enters into chemical combination with a part of the zinc, because, when melted for a length of time, all the zinc will be expelled with the exception of a small residuum, which is then retained with great force.

It is evident, therefore, considering that the character of alloys is as different as it may be, to judge from the foregoing, and considering further the great number of alloys now produced and used, that there must be great differences in their endurance. Neglecting the alloys of the precious metals, we may state generally that the different alloys of copper and tin are the most enduring. Pure bronze of this composition, polished, is not as easily oxidized in the air as other alloys. This is also proven by bronze relics dating from the time of ancient Egypt and other countries of antiquity, which bronze consists, almost without exception, of copper and tin. As a counterpart to this latter bronze, in the matter of endurance, may be mentioned an alloy

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of aluminum with about 30 per cent. of iron, which forms a hard and solid substance, but falls to powder in the course of a few days with the formation of malodorous gases, the gases formed being probably silicon-hydrogen.

For commercial uses, and especially for marine engine construction, the most important alloys are those of copper with tin, zinc, and, recently, with aluminum. They may be easily worked, and have great tensile strength and easily regulated toughness. For purposes of this kind, however, copper alloys must be durable not only in the atmosphere but also in sea water, whose destructive influences are immensely greater than those of the atmosphere. The literature on this subject offers little information, and a small chapter added on the subject of the endurance of copper alloys in sea water will probably be of interest to everybody.

The destruction of copper alloys does not proceed in sea water in the same manner as in air. In the latter case, as a rule, the oxidation proceeds uniformly all over the surface, while in sea water, with a number of copper alloys, pitting takes place. In certain cases one or the other constituent of the alloy is completely dissolved without altering the form or appearance of the specimen. Pitting takes place also with unalloyed copper exposed to sea water or acids, and may in this case be referred chiefly to lack of uniformity in density and hardness and to accidental impurities. The destruction of alloys with visible change of form and appearance of the surface is especially remarked in those containing a large percentage of zinc—brass for example. The fact that brass does not offer enduring resistance to atmospheric influences is well known. It oxidizes easily and thin sheets are soon destroyed. For this reason it would, for example, be impossible to use brass for telegraph and telephone wires, because the endurance would be small.

In this connection the results of experiments are interesting that were conducted by a manufacturer of copper and brass on a number of brass rods of 20 to 30 millimeters diameter exposed to the atmosphere. The bars consisted of 58 per cent. copper and 42 zinc, cast in the usual way and drawn. One-half of these bars

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were exposed for six months in spring and summer time in the open air during the time of the year when there was no frost. The other bars were stored for some time in a dry, closed room of the factory. The latter bars showed no change at the end of the time, while those exposed in the outside air were covered over their whole surface with innumerable small circumferential and longitudinal cracks. A similar appearance was shown by the bars exposed inside of the building for several winter months secured to one of the side walls; with this difference, however, that the surface cracks were to be found only on the side next the wall and in contact with the wall. These surface cracks are explained by the fact that the tensile strength of the outer skin had been impaired and that the metal had not then been able to resist the strains remaining after the drawing. Bronze bars annealed would probably not have shown this destructive action of the atmosphere.

The destruction of copper-zinc alloys in sea water is much more rapid than in air, and especially so if the alloy is brought into contact with other metals. The time necessary for the destruction differs with the composition, and probably also with the exposed surface of the metals with which the alloys are in contact; also, with the temperature of the water and other conditions. In certain cases it was observed that rolled sheets of copper-zinc alloys of 1.5 to 2 millimeters thickness reached the point of minimum strength after a period of six or eight months. The sheet, as it is taken from the water, is almost red in appearance; when burnished it assumes a somewhat lighter but still reddish color even when completely destroyed. The destroyed material may be broken between the fingers as easily as bread, and the fracture shows a reddish-brown copper color. Analysis shows that the zinc has been almost entirely consumed. As the outside form of material whose structure has been completely destroyed is, as a rule, unaltered, and as the red coloring of the surface is not apparent in dark spaces or under artificial light, it is difficult to learn by inspection whether the material has suffered. This would seem to be a serious danger on board ship, where the fracture of an outboard valve casing below the water

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line or of a propeller might hazard both human life and property.

In order to discover under what circumstances a rapid destruction of copper-zinc alloys takes place in sea water, and to discover those conditions under which this destruction does not take place; also to determine the endurance of other important alloys of copper with zinc, tin and aluminum in sea water, a number of experiments were undertaken. The manner of execution and the results of these experiments are reported in the following.

II. PLAN OF THE EXPERIMENTS.

Before beginning the experiments it was considered in what form, in what manner, and how long the material experimented on was to be subjected to the action of sea water, how the destruction was to be stated numerically; also whether and what similar experiments were to be conducted outside of sea water.

In the first place, it had to be determined in what manner the action of sea water on the alloys exposed to it or to atmospheric air was to be determined, because the form of the test specimens depended on it.

Measurement of the Destructive Effect.

If a rod of iron is exposed in moist air or in water, a layer of rust is formed on the surface whose thickness increases gradually. The surface in most cases is not attacked uniformly. On the contrary, the rust penetrates deeper in some places than in others. In any case, however, it is possible, after carefully cleaning the rod, to measure the corrosion that has taken place by the decrement of the cross section and of the weight. A decrease of the cross section, however, is not observed in the case of copper-zinc alloys, even after complete destruction of the original structure. The decrease in cross section, therefore, cannot, in the experiments in question, be taken as an indication of the endurance in sea water, because, in the first place, copper-zinc alloys were to be experimented on, and also because it was not known whether or no other copper alloys behaved in the same manner.

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The decrease in weight cannot be taken to furnish a direct measure of the destruction, as the weight of copper-zinc alloys is somewhat decreased by corrosion, but not decreased in the same proportion as the power of resistance of the material to mechanical stress. This fact is evidenced by the following table:

TABLE I.

No.	Alloy, Cu 57, Zn 42, Fe 1 (ab't).	Specific gravity.	Tensile strength.	Elongation.	Reduction of area, per cent.
1	Forged rod	8.6	39	21	23
2	Rod as in 1, much corroded in sea water, section unchanged	7.9	17	0	0
3	Corroded material picked from rod 2 after fracture	5.9	about 0	0	0

To obtain a measure of the destructive effect, it was decided therefore to measure the tensile strength and elongation of the material before and after immersion in sea water. It was at first intended to make a simultaneous exact measurement of the cross section and weight before and after the immersion, but this had to be given up on account of the added labor. Only an approximate determination of the cross section was attempted in what follows.

Form of the Test Pieces.

In order to be able to determine the loss of tensile strength and elongation of the test pieces, it was necessary to make them of such shape that they could be experimented on without subsequent change of form; otherwise the exterior corroded metal would have had to be removed more or less before such test could have taken place, which test would therefore have been that of the better preserved central portion. The test pieces were therefore made of the following shape and dimensions:

The test pieces of materials of high tensile strength were given a section of 17 by 8½ millimeters instead of 18 by 10, in order to be

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able to utilize a machine capable of pulling six tons. The results of the tests are not affected by these differences in the sections, because the comparison of tensile strength was made for equal dimensions.

As the same test pieces could not be subjected to tests both before and after immersion, each alloy was tested before immersion by means of a number of pieces taken from the same sheet as those immersed and representing the average. The pieces were preferably taken from sheet metal because experience has shown that the results so obtained are the most uniform.

Fastening of the Test-Pieces when Suspended in Sea Water.

Experience teaches—as stated above—that the corrosion of metals and alloys in sea water and its progress is augmented or delayed according as they are or are not in contact with other metals and depends on the nature of these metals. For example, an alloy consisting of aluminum 86, with an addition of copper, zinc, cadmium and silver, gave the following results:

TABLE II.—DESTRUCTION OF AN ALLOY RICH IN ALUMINUM.

No.	Kind of bar tested.	Tensile strength, kilogrammes per square millimeter.	Elongation, per cent.
1	Not immersed. Tested immediately after machining	10	3
2	Kept 24 months in the air	10	2
3	Exposed 24 months in sea water attached to a plate of same material	2 — 2.25	0
4	Exposed 16 months in sea water attached to a bronze plate	2 — 2.25	0
5	Exposed 8 months in sea water attached to a steel plate	2 — 2.25	0

The times necessary for the same destructive effect on the aluminum alloy are in the ratio of 1 : 2 : 3, according as the alloy is in contact in sea water with steel, bronze, or with the same material.

It is generally known that iron or steel is more easily and deeply pitted when in metallic contact with copper or bronze

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than when such contact does not exist; for example, iron rudder posts and rudders in proximity to bronze propellers or a hull plating of copper or brass are known to suffer. Ships' propeller shafts are not infrequently fractured on account of such corrosion, which takes place at the end of the bronze sleeves drawn over the shaft, where frequently the section of metal has been found to be reduced in the course of time to from four-fifths to three-fourths of the original area.

Corrosion of iron in contact in sea water with copper or bronze may be prevented, or at any rate delayed, by the use of zinc protectors placed in metallic contact with the iron.

It may not be so generally known that propellers, etc., made of copper-zinc alloys have a long endurance on iron ships, but are rapidly corroded on wooden ships sheathed with copper. The contact also between copper-zinc alloys and copper-tin alloys in sea water leads to a rapid destruction of the former. For example, the pintles of a ship's rudder made of Delta metal, working in bushings of tin-bronze, had lost their strength in the space of a few years.

It has been argued from these and similar experiences that electricity plays an important part in the destruction of metals in contact in sea water, that metal being attacked which is highest in the electrical potential series. Experiments conducted by Professor Finkener point in the same direction. The cause which led to the experiment of Professor Finkener was the destruction of the brass tubes and braces of the condensers of H. I. M. S. *Carola*. Professor Finkener immersed a number of cylindrical bars of 18-millimeter diameter of iron, zinc and other copper alloys for a lenth of time in a concentrated solution of common salt, and connected pairs of rods of different metals outside of the liquid by conducting wires.

Professor Finkener deduced the following conclusions:

1. A concentrated solution of salt corrodes zinc, iron, brass and bronze.

2. A concentrated solution of salt corrodes under similar circumstances two metals or alloys in the aggregate more when the latter are electrically connected than when they are insulated.

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3. A concentrated solution of salt corrodes of two metals or alloys electrically connected preferably the more electro-positive of the two, and when the difference, electrically, between the metals exceeds a certain magnitude it corrodes only the electro-positive element.

As regards the electrically connected bars of bronze and brass immersed in the solution of salt, the foregoing conclusions do not seem to be borne out. This would probably have been the case if, in addition to the determined decrease in weight, the loss in tensile strength and elongation had also been established. The corrosive effect would then probably have been much more clearly defined. The composition of the copper alloys is unfortunately not known.

If, as seems to be demonstrated, the electric current exercises important influence on the corrosion of metals in contact in sea water, it is important that every metal experimented on should be tested in contact with each of as large a series of other metals and alloys as possible. Practically it is, as a rule, of no importance whether a completely insulated metal endures well in sea water or not, because electrical contact with contiguous metals cannot be avoided. It is much more important for practical reasons to discover the best selection of material for the different parts in electrical contact in order to avoid rapid corrosion, selecting at the same time such metals as are best fitted for the purpose in a mechanical way. The test pieces of each alloy were consequently riveted to plates of other metals and alloys, having electrical contact with them, which plates were then suspended in sea water and insulated. This insulation was accomplished by lining a hole punched in the plate with hard rubber, the wire suspending the plate being, therefore, in contact with rubber only.

With the exception of the plates of iron, each of the plates had approximately the same superficial area as the test pieces attached to it. The plates of iron were so chosen that their surface was three or four times as great as that of the test pieces, in order to have something like the proportion existing between exposed surfaces of iron and copper alloys as they occur in ship construc-

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tion. The rivets for securing the test pieces to the plates were made of either the same material as the plates or as the test pieces.

The wire used for the suspension of bronze plates was phosphor-bronze of about 6 millimeters diameter. For iron plates iron wire of the same diameter was used. In the latter case insulation between the wire and the plate was unnecessary. At the upper end the wire extended about 1½ millimeters above the water and was fastened to iron nails driven into wood. In the case of the first plates prepared the suspending wire was not insulated. Special attention is directed to this in the analysis of the results.

In order to determine whether endurance could be predicated from the place of the metals and alloys in an electrical potential series, this series was fixed for the materials experimented on.

Time of Immersion.

The plates prepared as above described were suspended from a wooden bridge in the harbor of Kiel at a depth of from one to two meters below the surface. They were left there during summer and winter and were examined periodically. Only in a few cases did it happen that plates dropped off. A few test pieces were lost in consequence of the destruction of the rivets.

The time of immersion was fixed at first at two years. Of twelve pieces of any alloy which was to be experimented on in contact with a plate made of some other specific alloy, or of some pure metal, three test pieces were tested for tensile strength immediately after machining to shape; the remaining nine were riveted to the plate and immersed. After an exposure of eight months, one-third of these nine was taken and similarly tested, so that the tests were on sets of three pieces exposed for lengths of time of eight, sixteen and twenty-four months.

Subsequently, to simplify the experiments, six test pieces only were riveted to each plate, of which one-half were tested at the end of sixteen and the other half at the end of thirty-two months' immersion. The extension of time of immersion from twenty-four to thirty-two months appeared desirable in order to allow the corrosion of material to become more pronounced.

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Manner of Conducting the Tensile Tests.

In all cases the only treatment to which the pieces taken from the water was subjected was cleaning. In no case were they touched with a file or any other sharp instrument. They were cleaned first by washing, and, after drying, by rubbing off with fine emery cloth. Pits were not taken account of in so far as they were not allowed for in the determination of the tensile strength per square millimeter, as found by the testing machine.

In all cases the elastic limit was determined (being the stress at which an elongation of .2 of 1 per cent. became permanent), the ultimate tensile strength, the elongation and the contraction of area.

The area of cross section determined before testing was compared with the original section, as a measure of the reduction due to corrosion.

Corrosive Influences of the Atmosphere.

In order not to make the experiments too cumbrous, the corrosive influences of the atmosphere were observed on six alloys only, which were presumably least enduring in sea water, all containing much zinc. The test pieces were riveted to plates, as for those immersed in water, and were exposed in the open air not far from a chimney. After twenty-four months' exposure the pieces were tested and the results obtained compared with pieces of the same material tested immediately after machining.

III.—ALLOYS EXPERIMENTED ON.—SHORT SKETCH OF THE EXPERIMENTS.

Alloys Experimented On.

As already stated, the test in sea water was to be confined to those copper alloys which are at present in most extensive use in ship and marine engine construction, or whose use seems to be warranted in the future. Of most extensive use at present are the alloys of copper with tin and zinc, while those of copper with aluminum, the so-called aluminum-bronzes, will, doubtless, on account of their excellent qualities, be used more and more wherever rolled metal and forged pieces are required. For castings aluminum-bronze is not suitable, because it is exceedingly diffi-

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cult to obtain a casting solid and free from blow holes. The following is a list of the alloys that were tested.

a. Copper-zinc alloys containing a large percentage of zinc.

Copper-zinc alloys that may be forged red hot and which are known as yellow metal, naval brass, Muntz metal, Delta metal, Durana metal, iron bronze (Tobin bronze), etc., do not differ materially in their composition, because, in order to be forgeable, the constituents have to be combined in certain fixed proportions (from 58 to 63 Cu and 42 to 37 Zn). The tensile strength of a number of the alloys above referred to is augmented by the addition of about 1 per cent. of iron. Traces of lead, tin and manganese are frequently found. Manufacturers are in the habit of advertising alloys, particularly those containing iron, as being especially durable in sea water. Generally speaking, it is not to be assumed that there will be a marked difference in the durability of the various bronzes containing iron in sea water. It was, therefore, decided to test only one of them. Its composition was the following:

Copper,	56.01
Zinc,	41.99
Iron,	1.19
Lead,	0.82

This iron-bronze was tested in sea water and also in the atmosphere, in both cases in a forged condition, because this compound is not well suited for casting purposes. It is also to be assumed that the endurance of the casting would not differ materially from forged pieces.

The iron-bronze experimented on was placed in metallic contact with a plate consisting of metals as per the table following and under the conditions there detailed.

b. Copper-zinc alloys containing a small percentage of zinc.

For castings the following is specially to be recommended: Cu 86, Sn 9½, Zn 4½; also, Cu 88, Sn 8, Zn 4. These alloys make good castings, are hard enough for machinery purposes, have high tensile strength and great elongation. For these reasons cast specimens of this material were experimented on. The

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test pieces were taken from a plate which was cast of 88 Cu, 8 Sn and 4 Zn. During the exposure in sea water they were in contact with a plate of pure tin-bronze.

c. Pure tin-bronze.

Pure tin-bronze was used as a standard of comparison for the other alloys experimented on, tin-bronze being considered to be one of the most enduring of all alloys.

The material experimented on was a tough tin-bronze as used in ship and marine engine construction for parts exposed to contact with sea water. Its composition was 88 Cu, 12 Sn, and 89 Cu and 11 Sn. The use of these different compositions occurred through an error. The difference, however, is so small that the value of the experiments will not suffer, especially as in every case the composition of the particular test piece was known.

There was no phosphorus added to the tin-bronze purposely, because it is maintained by the inventors of phosphor-bronze, and with reason, that the addition of phosphorus increases the endurance of an alloy. Had phosphorus been added to the tin-bronze experimented on, and a given endurance established, doubt would have existed whether such result was due chiefly to the phosphorus or no.

The tin-bronze was exposed in water in metallic contact with different plates, as given in the subjoined table.

d. Pure aluminum-bronze.

The alloy experimented on consisted of Cu 91, Al 9, made of especially pure materials. With moderate tensile strength this material showed great elongation.

e. Aluminum-bronze containing iron.

An increase of tensile strength, and especially of the elastic limit, without doing mechanical work on the material, may be obtained by the addition of iron to aluminum-bronze. The increase of tensile strength is offset, to be sure, by a decrease of the elongation; still this remains sufficiently high where the percentage of iron is not too great. Aluminum containing silicon added to the alloy has the same effect as iron. An alloy containing iron and silicon was experimented on for its endurance in sea water. Its composition by weight was as follows:

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Copper,	88.13
Aluminum,	7.1
Silicon,	1.56
Iron,	2.74
Phosphorus,	0.02
Zinc,	0.50

The endurance of aluminum-bronze in sea water was watched with especial interest, because, in the first place, it is known that pure aluminum is rapidly corroded in sea water, and again because aluminum-bronze seems to be such a permanent alloy, such an intimate mixture, that a solution of the aluminum from the alloy ought not to be apprehended.

General Plan of the Experiments.

The following table gives an idea of the general plan of the experiments made on the alloys above stated:

Characteristic number of the test series.	Copper alloy experimented on.	Number of test pieces.	The test pieces were secured in metallic contact to a plate made from material as stated below.	Material of the suspension wire.	Suspension wire insulated.*	The test for endurance took place.
A1.	Iron-bronze (copper alloy containing a large percentage of zinc and no tin).	Fifteen. (1–15)	Tin-bronze of 95 copper, 5 tin.	Bronze wire.	No.	In sea water and in the atmosphere.
A2.	Do.	Nine. (16–24)	Casting of iron-bronze (copper alloy with small percentage of zinc, without tin).	Do.	No.	Do.
B1.	Do.	Twelve. (25–36)	Oak wood.	Do.	No.	In sea water only.
B2.	Do.	Six. (37–42)	Iron.	Iron wire.	...	Do.
D.	Do.	Nine. (61–69)	Pure aluminum-bronze.	Bronze wire.	Yes.	Do.
C2.	Tin-bronze containing a small percentage of zinc.	Nine. (52–60)	Tin-bronze of 88 copper, 12 tin.	Do.	No.	Do.
C3.	Do.	Nine. (196-204)	Do.	Do.	Yes.	Do.

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Characteristic number of the test series.	Copper alloy experimented on.	Number of test pieces.	The test pieces were secured in metallic contact to a plate made from material as stated below.	Material of the suspension wire.	Suspension wire insulated.*	The test for endurance took place.
C1.	Pure tin-bronze (88 copper, 12 tin).	Nine. (43–51)	Tin-bronze of 88 copper, 12 tin.	Bronze wire.	No.	In sea water only.
E2.	Pure tin-bronze (89 copper, 11 tin).	Nine. (79–87)	Tin bronze of 89 copper, 11 tin.	Do.	Yes.	Do.
E1.	Do.	Nine. (70–78)	Electrically-deposited copper.	Do.	Yes.	Do.
E3.	Do.	Nine. (88–96)	Forged iron-bronze.	Do.	Yes.	Do.
E4.	Do.	Nine. (97-105)	Iron.	Iron wire.	...	Do.
E5.	Do.	Nine. (106 114)	Pure aluminum-bronze.	Bronze wire.	Yes.	Do.
F1.	Pure aluminum-bronze.	Nine. (115 123)	Electrically-deposited copper.	Do.	Yes.	Do.
F2.	Do.	Nine. (124-132)	Pure aluminum-bronze.	Do.	Yes.	Do.
F3.	Do.	Nine. (133 141)	Tin-bronze of 89 copper, 11 tin.	Do.	Yes.	Do.
F4.	Do.	Nine. (142 150)	Forged iron-bronze.	Do.	Yes.	Do.
F5.	Do.	Nine. (151-159)	Iron.	Iron wire.	...	Do.
G1.	Aluminum-bronze.	Nine. (160 168)	Electrically-deposited copper.	Bronze wire.	Yes.	Do.
G2.	Do.	Nine. (169-177)	Aluminum-bronze containing iron.	Do.	Yes.	Do.
G3.	Do.	Nine. (178-186)	Tin-bronze of 89 copper, 11 tin.	Do.	Yes.	Do.
G4.	Do.	Nine. (187-195)	Iron-bronze.	Do.	Yes.	Do.

* The suspension wire made of bronze of about 94 copper and 6 tin with a percentage of phosphorus, was or was not insulated from the plate by means of vulcanized rubber.

REMARKS. A1.—Test pieces 1 to 24 were planed from the same forged plate.

A2.—This test was intended to establish the endurance of iron-bronze in sea water when not in contact with any other metal. The desired conditions were not, however, entirely realized, because, in the first place, the bronze wire was not insulated from the suspended plate; and furthermore, because the suspended plate was made by recasting iron-bronze, whereby about 4 per cent. of the zinc was lost by burning out.

B1.—In this case, also, it is probable that an electric current was established between the suspension wire and the iron-bronze, wet oak wood being an imperfect non-conductor.

C2.—Open to objection, because the suspension wire was not insulated.

C3.—Repetition of the preceding test with suspension wire insulated.

C1.—Open to objection, because the suspension wire was not insulated.

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IV. RESULTS OF THE EXPERIMENTS.

These are stated in a number of tables combined with photographs of the test specimens, showing their appearance after immersion, the reproduction of which would be inexpedient, and for which the reader is referred to the original article published in the "Marine-Rundschau," November, 1898. A resumé of the general results will be given under sub-head VI.

V. GALVANIC SERIES OF THE ALLOYS.

A galvanic series was constructed in which are placed all the alloys experimented on, as well as those composing the suspension plates, and also the pure metals that entered into the composition of the various alloys. The alloys and metals whose place in this series was determined had not, at the time of such determination, been in contact with sea water. The determination was made by the Government's Physical-Technical Institute with the utmost care, and the following series was determined:

+ Zinc,
{ Aluminum,
{ Iron,
Tin,
Iron-bronze,
{ Pure aluminum-bronze,
{ Aluminum-bronze containing iron,
{ Pure tin-bronze (89 Cu, 11 Sn),
{ Bronze containing small percentage of tin (88 Cu, 8 Sn, 4 Zn),
{ Copper,
— { Phosphor-bronze (94 Cu, 6 Sn and phosphorus).

The metals inclosed by brackets are very close in the potential series. It is to be remarked that clear iron is much below aluminum on the above scale, but as it rusts it moves towards the zinc end of the line. The contrary should have been expected, but the phenomenon is probably due to the presence of hydrogen, which is freed by the chemical processes. A similar phenomenon is observed with bronzes containing iron. After continued exposure to sea water the surface becomes much pitted and has the color of copper. Trustworthy chemical analyses of this alloy

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have demonstrated that the effect of the sea water is to dissolve out the zinc. In this case also the metal should approach the negative end. Its motion towards the positive end, however, again finds its probable reason in the occlusion of hydrogen.

Pure aluminum-bronze is more nearly like aluminum in the potential series owing to its higher percentage of aluminum than is aluminum-bronze containing iron. It is further to be remarked that phosphor-bronze is the most electro negative of all the alloys and metals experimented upon.

The two tin-bronzes experimented upon (bronze containing a small percentage of zinc and pure tin-bronze) and also copper are so nearly alike electrically that their relative position in the series is indeterminate.

Independent of the question of electrical potential of the metals in sea water is that of the chemical changes undergone by the several metals and alloys when insulated. Bars of the eleven metals experimented on were insulated from one another by means of pieces of glass and immersed in a vessel containing sea water from the Baltic for nearly three months. In the mean time the water was renewed once. Weighings before and after the immersion showed that several of the bars had suffered a decrease; viz: iron, zinc, tin, iron-bronze and phosphor-bronze. The more exact determination of these relations, however, was beyond the scope of the experiments.

VI. PRACTICAL RESULTS OF THE EXPERIMENTS.

In general, it may be stated that the endurance of copper alloys in sea water is dependent chiefly on the metals with which they happen to be in contact. The following conclusions may be noted:

a. Endurance of iron-bronze in the atmosphere.

Forged iron-bronze resisted atmospheric influences very well. Tensile strength and elongation were unchanged after two years' exposure. Except for a slight oxidation of the surface the test pieces showed no change in appearance, in form, and in structure. A similar result may be expected of castings of this material. On the other hand, it may be predicted, judging from

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experiments with copper-zinc alloys, that hard drawn or otherwise cold worked iron-bronze will resist atmospheric influences not so well in consequence of unequal density.

The question whether copper-zinc alloys resist atmospheric influences as well as the iron-bronze experimented on was not inquired into. It is to be presumed, however, that the presence of iron does not only change the characteristics as to the tensile strength and density, but also has a beneficial influence on the endurance in the atmosphere. This supposition is based on the fact that iron-bronze, in the absence of electric currents, is less subject to attacks by acids and acrid fluids than other similar alloys not containing iron.

b. Endurance of copper alloys in sea water.

1. Iron, tin and aluminum-bronze in contact with iron resisted the action of sea water very well.

After two and two and one-half years' exposure in sea water attached to iron the alloys preserved all their characteristics. There was no semblance of deterioration. It was not determined whether the test pieces had suffered a decrease in weight. Probably there was none, as the form of the pieces remained unchanged, and a solution of the zinc, tin or aluminum was out of the question, considering the results of physical tests. This result is in accordance with the results of Professor Finkener and his hypothesis that, with an electric current passing between metals in contact in sea water, the more electro-positive element only is attacked—the iron in this case.

2. Forged iron-bronze in contact with tin bronze was destroyed in sea water in a short time by the solution of the zinc.

In contact with aluminum-bronze the destruction proceeded more slowly, still it was rapid, so that the use of iron-bronze in combination with aluminum-bronze for parts subject to the action of sea water appears inadmissible.

In contact with tin-bronze, iron-bronze had lost after a lapse of two years two-thirds of its original strength and four-fifths of its elongation. The structure of the material had been reduced in spots to two-thirds of the original sectional area by the more or less complete solution of the zinc, which, however, was not

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observed until after the pieces had been broken in the testing machine. The tin-bronze experimented on contained only 5 per cent. of tin. It is probable that a bronze containing a larger percentage of tin would not have led to such rapid destruction. Cast-iron-bronze or iron-bronze hammered, or otherwise worked by mechanical means, will probably behave in the same way as forged-iron-bronze.

In contact with aluminum-bronze, iron-bronze had lost, after an exposure of sixteen months, about one-third of its original tensile strength and elongation. The structure of the material had been reduced in spots to nearly three-tenths of the original section. The pieces taken from the water and cleaned presented no marked change of surface except for small, pale red spots.

The rapid destruction of iron-bronze in contact with tin-bronze is to be explained by the large interval between the two metals on the electrical potential series. The difference between iron-bronze and aluminum-bronze is not so great, and as a matter of fact the destruction of iron-bronze in contact with aluminum-bronze proceeded less rapidly.

3. Forged-iron-bronze in contact with a plate of the same material (with, however, about 4 per cent. less zinc, which was lost during melting and casting) was rapidly destroyed. The plate had been suspended by a phosphor-bronze wire which had not been insulated.

After an exposure of two years the iron-bronze had lost in round numbers 65 per cent. of its original tensile strength. The structure of the material had been reduced in places to about three-fourths of the original section.

In all probability the cause of this rapid deterioration was the bronze suspension wire. We may conclude that a large piece of iron-bronze will be rapidly destroyed in sea water, even when in contact with a relatively small piece of tin-bronze.

4. Iron-bronze and tin-bronze containing phosphorus insulated from one another in sea water by means of a block of oak wood, resulted in a slowly progressive destruction of the iron-bronze.

The test pieces of iron-bronze had lost, after an exposure of

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twenty-three months, about 20 per cent. of their original tensile strength and about 25 per cent. of their elongation. The structure of the material near the surface was destroyed to a depth of about .5 millimeters, which was discovered when they were broken in the machine. The destruction must be ascribed chiefly to the electric current induced between the bronze pieces and the phosphor-bronze suspension wire, because copper-zinc alloys not in electrical contact with other metals were not as rapidly destroyed. Otherwise it would not be possible to use this material for the sheathing of wooden vessels, which is common practice.

5. Tin-bronze containing a small percentage of zinc (88 Cu, 8 Sn, 4 Zn), in contact with pure tin-bronze, was attacked in sea water no more vigorously than pure tin-bronze insulated or electrically connected with tin-bronze containing a smaller percentage of tin with an addition of phosphorus.

The observed comparatively slight effect of sea water on this bronze in contact with pure tin-bronze is to be explained by the proximity of these alloys on the electrical potential series. It seems remarkable and inexplicable that bronze containing little zinc suffered more when the plate to which the specimens were attached was insulated from the suspending wire than when it was not so insulated.

Judging from the experiments, it does not seem necessary to exclude tin-bronze containing a small percentage of zinc from use for parts exposed to sea water. The tensile strength and elongation do not suffer more than in the case of pure tin-bronze, and the latter is just as much subject to pitting as tin-bronze containing zinc. It appears, however, that it is well to be cautious in the use of this alloy, in view of the fact that alloys containing much zinc do certainly corrode rapidly in sea water. The experiments are not conclusive in showing that tin-bronze containing zinc and pure tin-bronze are equally enduring. On the contrary, the author is of the opinion that pure tin-bronze is to be preferred for parts in constant contact with sea water.

6. Pure tin-bronze in contact with iron-bronze or with aluminum-bronze was very enduring; insulated, the endurance was

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not so good. The corrosion was most rapid in contact with copper.

The results of the tests go to show that the endurance of pure tin-bronze in sea water depends, as in the case of other alloys, in great measure on the metals with which it is placed in contact. The most rapid destruction occurred when in contact with copper, in accordance with their difference on the potential series, though this difference is small.

In another test in which both plate and specimens were made of tin-bronze (in which, however, the suspension wire was of phosphor-bronze not insulated from the plate) the corrosion of the tin-bronze was as marked as when in contact with the copper plate. The position of phosphor-bronze at the negative end of the potential series furnishes an explanation.

7. The decrease in tensile strength and elongation from 6 to 7 per cent. of tin-bronze in contact with iron-bronze appears subject to question.

In the first place, the pieces after exposure presented no change in appearance. Furthermore, tensile strength and elongation were greater after exposure of thirty-two months than at the end of sixteen months. It may, therefore, be concluded that the quality of the test pieces broken immediately after machining was better than that of those immersed in sea water. It is well known that complete homogeneity of material cannot be obtained in castings.

8. Pure aluminum-bronze has proved itself to be as enduring in sea water as pure tin-bronze.

Pure aluminum-bronze exposed for thirty-two months in sea water, in contact with iron and with iron-bronze, was, generally speaking, unchanged. Insulated or in contact with copper a slight change was noticeable.

The most effective corrosion, relatively speaking, had attacked those pieces that were placed in contact with tin-bronze, although even in this case tensile strength and elongation had suffered very little. The quality of the material was much better than the appearance of the test pieces seemed to indicate. The tin-

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bronze plate to which the aluminum-bronze pieces were riveted had also been attacked.

In such cases where the pure aluminum-bronze was the more electro-negative metal (that is, in contact with iron and iron-bronze) it remained unattacked. A slight corrosion was noticeable in those cases where the aluminum bronze was the more electro positive metal, that is, in contact with tin-bronze and with copper. However, in these cases the corrosion was no greater than that of insulated test pieces. On the whole, judging from the results obtained, it may be stated that aluminum-bronze is less subject to deterioration by galvanic action than other copper alloys. While the good endurance of tin-bronze may be chiefly ascribed to its low position in the electrical series, the endurance of pure aluminum-bronze will probably find its cause in the fact that the constituents of this compound are more intimately combined, perhaps form a chemical compound.

9. Aluminum-bronze containing iron has proved itself to be less enduring than pure aluminum-bronze. It is, as far as endurance is concerned, somewhat inferior to tin-bronze.

In contact with iron-bronze, sea water had no effect on aluminum-bronze containing iron. The pieces in contact with copper suffered most, but in this case also the comparatively small sensitiveness of aluminum-bronze to galvanic action above referred is noticeable. The corrosion of test pieces suspended in contact with copper was not much greater than that of insulated pieces, and in the latter case a more pronounced corrosion took place than in the case of pieces suspended in contact with tin-bronze. The fact that aluminum-bronze containing much iron is more subject to corrosion than pure aluminum-bronze is evidenced by the fact that this material when moistened by sea water displays rust spots. This leads to the conclusion that the iron is not homogeneously distributed throughout the alloy, is not intimately combined with it, although, to judge from the influence which iron has on the tensile strength of aluminum-bronze, the contrary should have been expected.

10. In general, the results go to show that a rapid deterioration of copper alloys in sea water is to be prevented by selecting

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such alloys and metals as are close together in the electrical potential series, wherever the insulation of the several materials is not possible.

In any case, regard must be had to both metals in contact so that the preservation of one will not lead to the rapid deterioration of the other. For example, tin and iron-bronze in contact with iron both endure well; the iron will, however, suffer least when in contact with iron-bronze.

Under certain circumstances it may not be objectionable to allow a more rapid deterioration of a metal which is sufficiently heavy to stand the loss in order to save another and thinner part. In such cases, the use of iron-bronze might be admissible whenever it is not possible or desirable to use either iron or pure zinc protectors. The use of alloys containing a large percentage of zinc is permissible only in cases where they are not in electrical contact with other copper alloys.

Pure aluminum-bronze seems especially well adapted for parts in contact with sea water, because it corrodes very little in contact with more electro-negative metals and produces little destruction of electrically connected more electro-positive metals.

11. An addition of phosphorus moves a metal towards the negative end of the potential series and appears to enhance its endurance.

No direct experiments were made on the endurance of phosphor-bronze in sea water, but from general observations made on wires used for suspending the plates, as also judging from practical experience, it seems proven that the endurance of phosphor-bronze in sea water is very good. For this reason drawn phosphor-bronze wire and bars are very suitable for screws, bolts, studs, etc., in castings of tin-bronze where they are exposed to sea water. A rapid destruction of the tin-bronze on account of such screws, bolts, and so on, is not to be feared. It is good practice to add to tin-bronze castings a small percentage of phosphorus in order to make the melted metal more fluid, and also to make it more enduring in sea water, whenever it is not brought in contact with other metals whose destruction might thereby be made more rapid.

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It would be interesting to determine whether phosphor-bronze in contact with copper in sea water would not lead to the destruction of the latter metal. It is possible that the observed rapid destruction of copper pipes, copper vanes, of condenser circulating pumps, etc., may be due to the phosphorus contained in the bronze with which they are in contact.

To the results obtained with the copper alloys in sea water I wish here to add an experiment with steel containing a high percentage of nickel. According to this experiment, nickel-steel, which is a most valuable material on account of its high tensile strength and tenacity, suffers by galvanic action much more than iron and carbon-steel. Nickel-steel containing about 30 per cent. of nickel, when placed in contact in sea water with tin-bronze, showed after a very short time small pits of considerable depth, which were not observed with carbon-steel.

In connection with the results on the endurance of alloys, it might also be of interest to note the growth of shells on the specimens exposed in sea water. It may also not be amiss to call attention to the tendency to the formation of verdigris on the surface of specimens that had been exposed when they were subsequently stored in a dry place.

The growth of shells was most pronounced and proceeded most rapidly on plates of iron. After that came those of iron-bronze, and their growth was greater in cases where test pieces of tin-bronze were fastened to the iron-bronze plate than when the test pieces were of aluminum-bronze. It would almost seem to indicate that the electro-motive force called into existence by the contact of the dissimilar metals favored the growth of the shells. The observations, however, are not complete enough to make definite conclusions possible.

Certain of the plates that had been exposed in sea water were, after cleaning and testing, placed in a dry room. The greater part of the specimens retained their metallic color, while the rest became covered with a more or less heavy coating of verdigris. Observation showed that the formation of cupric oxide occurred only on specimens of certain experimental series. It did not depend upon the material of the test specimen, but appeared to be

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connected with the degree of surface corrosion, which latter was conditioned by the material of the plate with which the specimens had been in contact. It was most pronounced in the case of those specimens which, after exposure in sea water, showed a spotted black and red appearance of the surface.

In conclusion, it is to be remarked that the experiments conducted are not a complete solution of the question of the endurance of metals in sea water. It is hoped, however, that this contribution will lead to further trials which will get nearer the mark. In such a case, the results here obtained may be of use in indicating how the experiments might be better conducted. One of the points to which attention might be directed would be the choice of the same material for the contact plates and for the wires or ribbons that serve for their suspension. The exact weighing of the test specimens before and after exposure is also recommended, because, without this observation, the results are not as complete as they should be.

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TRIALS AND EXPERIMENTS MADE IN H. M. S. *ARGONAUT.*

By Sir John Durston, K. C. B., R. N., Engineer-in-Chief of H. M. Navy.

[Read at the Fortieth Session of the Institution of Naval Architects, March 22, 1899.]

The following paper gives an account of the results of the contract trials of H. M. S. *Argonaut*, and certain experiments made while these were being carried out. Advantage was taken of the opportunity of making measurements of the actual water consumption of the engines under various conditions, with special measuring tanks fitted for this purpose.

The *Argonaut* is a twin-screw cruiser of 18,000 I.H.P.

The experiments were carried out on the specified contractors' trials, viz: the thirty hours' trial at 3,600 I.H.P., a trial of the same duration at 13,500 I.H.P., and the full-power trial of eight hours at 18,000 I.H.P.

The engines are of the same dimensions and arrangement as those of the *Diadem*, described and illustrated in the paper read last year. They consist of two sets of triple-expansion engines, arranged in separate engine rooms divided by a middle-line bulkhead, and are designed to develop the full specified power with an initial pressure at the engines of 250 pounds by gage. The boiler pressure is 300 pounds.

The diameters of the high, intermediate, and each of the two low-pressure cylinders are 34 inches, 55½ inches, and 64 inches, respectively. The stroke is four feet, and the designed revolutions are 120 per minute, or ten more than the designed speed of revolution of the *Diadem*.

Each cylinder has a separate working barrel, which forms a steam jacket with the cylinder walls. Steam may be admitted to these jackets and maintained at any desired pressure. The condensed jacket steam is led to collectors furnished with gage glasses, and drained into the main condensers by screw-down valves.

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The cylinders are arranged high and intermediate forward, and the two low pressures aft. The two forward cranks being opposite one another, the two after cranks are also opposite one another, but at right angles to the two forward cranks. On all the trials there was an entire absence of vibration of the ship.

The high and intermediate cylinders are fitted with piston, and the low pressures with double-ported flat slide valves; these are actuated by the ordinary link motion. The reversing gear is of the "all round" type usual in naval engines, and provision is made for adjusting the position of each link independently.

There are a feed and a hot-well tank in each engine-room wing, these are fitted with connecting pipes to the corresponding tanks on the other side of the ship.

Steam is supplied by thirty Belleville boilers of the economizer type. They are arranged in four groups, back to back, and are stoked in the fore-and-aft direction. Transverse bulkheads divide the boiler space into four separate compartments.

The total heating surface provided is 47,300 square feet, consisting of 28,300 square feet in the generator portion and 19,000 square feet in the economizer portion, as against a total of 40,550 square feet in the *Diadem*, viz: 29,600 square feet in generator and 10,950 square feet in the economizer portions respectively. It will be noted the proportion of economizer to generator heating surface is much larger than in the *Diadem*, but the proportion in the latter was due to her boilers having been altered to economizer type while in course of construction. The exact proportion, however, is not definitely settled, and, so far as experiments have gone at present, the ratio of these two surfaces may vary considerably without affecting economy, as long as practically the same total heating surface is maintained. The grate area is 1,390 square feet.

There are two main condensers with a total cooling surface of 19,000 square feet. Each is provided with circulating water by two independent centrifugal pumps, 45 inches in diameter, placed in its own engine room. Bilge suctions are fitted to these four circulating pumps, and each is capable of discharging 1,200 tons of water per hour from the bilge. There is in each engine room

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a hot-well pump, for taking water which has been delivered by the main or auxiliary air pumps to the hot well tank, and discharging it through a filter to the feed tank; an evaporating and distilling plant, the two being capable of making ninety tons of water per day when worked non-compound, and fifty-six tons when worked compound, for the boilers, or thirty-two tons per day for drinking purposes, and the usual auxiliary condenser for condensing the exhaust steam from the auxiliary engines; this condenser furnishes a cooling surface of 1,100 square feet, and has its own circulating and air pumps.

Besides these, a steering, a ventilating, an electric light, and two fire and bilge engines are placed in each engine room; a third electric-light engine being situated in another compartment.

Each of the stokeholds has its furnace air-pumping and ventilating fan, and each boiler room a main and an auxiliary feed engine.

Outside the machinery space there are engines for air-compressing, boat, coal, and ash hoisting, capstan working, refrigerating, &c.

The *Argonaut's* trial took place in the English Channel.

The trial at 13,500 I.H.P. taking place on November 29 and 30, 1898, that at full power on December 3, and at 3,600 I.H.P. on the 12th of that month. The displacement of the vessel on all the trials was about 11,070 tons, and speeds of 21.14, 19.94, and 13.16 were observed over a measured course of 23 knots for the full, continuous steaming, and 3,600 I.H.P. trial respectively.

Class.	Description of trial.	Trial.								Weights.	
		Duration, hours.	Revolutions.	Piston speed.	Steam presure.		I.H.P. developed, mean.	Air pressure.	Coal per I.H.P. per hour.	Machinery, complete.	Boilers, complete.
					Boilers.	Engines.					
Diadem	3,300 I.H.P.	30	67.9	543.8	218.5	160.5	3,339	.....	2.04	1,540	767
	12,500 I.H.P.	30	106.5	852.0	267.0	230.0	12,785	.....	1.71		
	Full power.	8	116.6	933.2	286.5	236.7	16,961	.....	1.73		
Argonaut.....	3,600 I.H.P.	30	73.1	584.8	238.0	138.0	3,784	.....	2.03	1,578	787
	13,500 I.H.P.	30	112.6	901.0	260.0	220.0	13,932	.....	1.66		
	Full power.	8	123.6	989.0	291.0	257.5	19,025	2	1.64		

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Class.	Description of trial.	Surfaces.		I.H.P. per ton (Mean I.H.P.).		Weight in lbs. per I.H.P. (Mean I.H.P.)			I.H.P. per sq. ft. of grate. (Mean I.H.P.)	Heating surface per I.H.P. (Mean I.H.P.)
		Grate. Sq. ft.	Heating. Sq. ft.	Machinery complete.	Boilers.	Engines.	Boilers.	Total.		
Diadem	3,300 I.H.P.	.....	.....	.....	.....	.....	.....	.....	.....	.....
	12,500 I.H.P.	1,460	40,990	8.30	16.66	135	135	270	8.75	3.20
	Full power.	1,460	40,990	11.01	22.11	103	101	204	11.60	2.41
Argonaut.....	3,600 I.H.P.	.....	.....	.....	.....	.....	.....	.....	.....	.....
	13,500 I.H.P.	1,390	47,300	8.89	17.70	127	127	254	10.02	3.39
	Full power.	1,390	47,300	12.05	24.17	93	92	185	13.69	2.49

A table is appended showing the average weights of machinery and heating surfaces of the boilers of the ships of the *Diadem* class, and of two ships of the *Argonaut* class, which have made their steam trials.

In comparing the figures, it will be seen that there is a decrease of grate surface in the *Argonaut*. This is due to the fact that the proportion of heating surface was increased in the economizer; the corresponding reduction of generator surface (the number of stages in the element remaining the same) leading to a decreased number of elements, and, consequently, of fire grate in proportion to the power.

As to the efficiency of these arrangements, it will be seen that the consumptions of coal in the case of the *Argonaut* class are slightly smaller than in the *Diadem* class; while, due to the substitution of economizer for generator-heating surface, and to the increase of the number of revolutions in the engines, there is a decrease in weight per indicated horse power of about 9 per cent.

The water-measuring appliances were arranged primarily to ascertain the quantity of steam used for the main engines under various conditions as regards jacketing of cylinders, steam pressure, and rates of expansion. Opportunity was also taken to make certain observations as to the amount of steam used by the auxiliary engines, but this was not the principal object in view, and the various alterations of pipes necessary to enable an accurate separation to be made between the steam used by the

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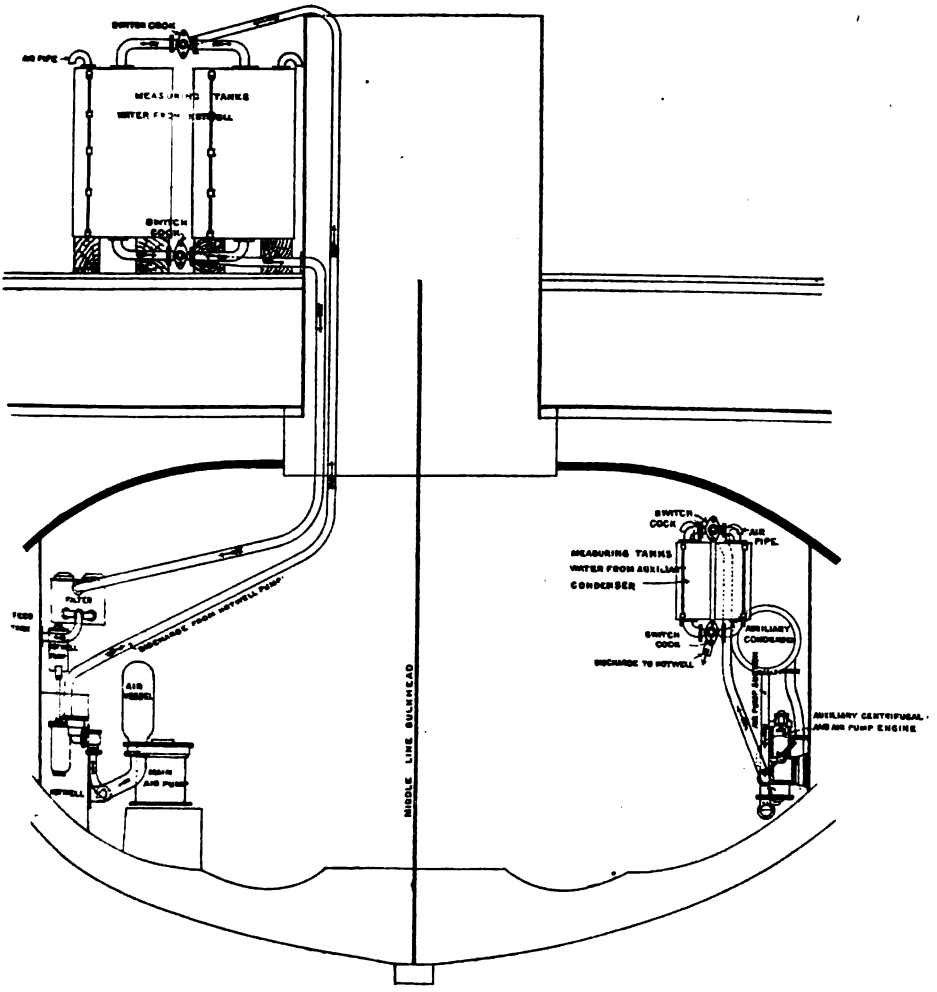
H. M. S. "ARGONAUT"

WATER MEASURING APPARATUS



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auxiliary engines necessary for the propelling engines, and the other auxiliary engines of the ship were not made.

The arrangements adopted may be briefly described as follows: First, in order to measure the total water passing through the main and auxiliary condensers, the hot-well pump discharges were disconnected from the grease extractors and connected in each case to a pair of measuring tanks placed on the upper deck, as shown in the diagram. These were alternately filled and emptied, the water, when measured, flowing by gravity through the grease extractors into the feed tanks. Each of the four tanks was of 240 cubic feet capacity, which gave about five-minute intervals between the times of switching from one tank to another when running at full power. It was arranged that the only steam or water entering the main condenser except that from the separator, which was measured and allowed for, was that from the main engines and their jacket drains, so that the economy or otherwise of the various methods of working the main engines could be exactly ascertained.

To measure the water passing through the auxiliary condenser, the auxiliary air pump discharges were disconnected from the grease extractors and arranged to discharge to small measuring tanks of about thirty cubic feet capacity. As in the case of the large tanks, these were fitted in pairs; they were placed on the upper engine-room platform, and the water was run from them to the hot-well pump suctions, its quantity being thus included in the amount measured by the large tanks on the upper deck. The difference in the quantities of water measured by the small and the large tanks thus gave (subject to the allowance named above) the water used by the main engines and jackets. The diagram shows in principle the arrangement of tanks and connections employed, unnecessary detail being eliminated for the sake of clearness. Identical arrangements were made for measuring both the total and auxiliary water from each engine room.

The slide valve settings in full gear, as actually measured, give the following cut-offs in the respective cylinders: High pressure, 73 per cent.; intermediate pressure, 67 per cent.; and

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low pressure, about 46 per cent. of the stroke. The cut-offs used during the trials are given in the tables.

It should be observed here that, as arranged for convenience of comparison in the tables, the order is that of the total ratios of expansion. The alphabetical order of the reference letters gives the actual sequence of the trials. The general scope and results of the tests made are shown in the tables.

Referring to Table I, which deals with the eight hours' full-power trial, the main linking gear was run out to "full gear," and the high-pressure independent gear was used as found necessary to maintain the required power. The steam pressure at the engines varied from 236 pounds to 244 pounds, and that at the boilers from 290 pounds to 299 pounds. The real ratio of expansion was 8.5 throughout the trial.

The trial was started with the jackets out of use. After three hours the low-pressure jackets were filled with steam of about twenty pounds pressure above that in the receiver, and remained in use for the remainder of the trial.* For the last two hours, the other jackets were also brought into use, the pressure maintained in the intermediate being about twenty pounds above that in the receiver; but that maintained in the high-pressure jacket was not so high as its receiver pressure, it being apprehended by the contractors that the cylinder walls might become too dry for efficient working at the high piston speed required for maximum power.

Turning to Table II, which deals with the trial at 13,500 I.H.P., or the maximum continuous steaming power, it will be observed that the conditions of initial pressure and ratio of expansion varied considerably throughout the trials. The thirty hours was divided into six periods of four and one-half hours each, and one of three hours' duration.

In trials G, C, D the main and high-pressure independent linking gears were used to regulate the power. In trial G, with 12.5 expansions, all the jackets were in use, the pressure of the receiver being maintained in the high-pressure jackets, and

* In dealing with the tables and the following description it should be borne in mind that the engines are jacketed on the cylinder barrels only.

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pressures above those in their corresponding receivers in the intermediate and low-pressure jackets. In trial C, with 10.4 expansions, the intermediate and low-pressure jackets were used, the pressure maintained in them being in excess of their received pressure, while in trial D, with the same ratio of expansion, all the jackets were shut off. The steam pressure at the engines during these three trials varied from 229 to 248 pounds, and the boiler pressure from 251 to 280 pounds.

In trial F the main linking gear only was used to regulate the power obtained, the slide valves of all the cylinders being thus linked up. In this case 9.7 expansions were given, and the steam at engines and boilers was respectively 235 and 275 pounds. No jacketing was used on the cylinders.

In trial B, with 9.1 expansions, the main links were run out to full gear, the high-pressure independent link being used to obtain the cut-off; in this case steam of 287 pounds was used at the boilers and 190 pounds at the engines, and, as before, no jacketing was used.

In trials A and E, again, the jackets were out of use, all the slide valves were in full gear, and the total expansion was 8.3 times. In trial A the steam pressure at boilers was 194 pounds and in trial E 232 pounds, the pressures shown at the engines being about 170 and 180 pounds respectively, the difference between these two trials being that in one case the boiler steam was of higher pressure and reduced more by throttling than in the other.

In Table III it will be seen that the thirty hours' trial at 3,600 I.H.P. was divided into six equal periods, each of five hours duration.

In trials A, B and C, the main and high-pressure independent linking gears were set to obtain the required power, the total expansion being 15.7 and the steam pressure at engines being about 168 pounds, and averaging 285 pounds at the boilers. In trial A the high-pressure jacket carried nearly the same steam as the receiver; the intermediate and low-pressure jackets being maintained at about 20 pounds above theirs. In trial B the high-pressure jacket was not in use, the steam pressure in the other

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I.H.P.

Port.			Vacuum.		Temperature of feed water.		Cut-off in cylinders (percentage of stroke). Starboard.				Port.			
I.	F.L.	A.L.	S.	P.	S.	P.	H.	I.	F.L.	A.L.	H.	I.	F.L.	A.L.
115	62	60	26.0	25.4	114	116	71	67	46	46	71	67	47	46
...	57	57	25.8	25.7	115	113	71	67	46	46	71	67	47	46
...	...	...	26.0	25.2	113	117	71	67	46	46	71	67	47	46
I.H.P.														
00	36	39	26.7	26.5	102	101	43	48	31	31	42	47	32	31
01	44	44	26.6	26.6	100	104	54	57	38	38	52	56	39	37
.	...	...	26.8	26.5	103	104	54	57	38	38	52	56	39	37
.	...	...	27.1	27.0	102	105	60	52	34	35	58	52	35	35
.	...	...	26.6	26.4	101	102	65	67	46	46	65	67	47	46
.	...	...	26.2	26.1	104	106	73	67	46	46	73	67	47	46
.	...	...	26.8	26.2	104	106	73	67	46	46	73	67	47	46
.H.P.														
9	29	29	26.0	25.8	110	110	28	34	23	23	26	31	23	22
0	30	30	25.8	26.0	107	106	28	34	23	23	26	31	23	22
..	...	...	25.5	26.0	110	109	28	34	23	23	26	31	23	22
.	...	...	25.5	26.0	106	107	39	34	23	23	36	31	23	22
.	...	...	26.1	26.4	107	101	65	67	46	46	65	67	47	46
	...	...	26.2	26.7	91	90	73	67	46	46	73	67	47	46

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jackets being maintained as in A. In trial C, as in the succeeding trials D, E, F, the jacketing was entirely shut off.

In trial D the main links only were used to obtain an expansion of 13.2, the steam at the engines being 142 pounds with a boiler pressure 280 pounds.

In trial E the main linking gear was in full gear, the high pressure independent gear only being used to obtain the cut-off. 9.1 expansions were given to the steam; the pressure at the engines being about 78 pounds and at boilers 285 pounds, this was reduced by throttling.

In trial F, all the links were placed in full gear, and with a total expansion of 8.3, 68 pounds was the pressure used at engines, and 130 pounds at boilers to obtain the power. No lower boiler pressure than this being practicable on account of the working of the electric-light and steering engines.

Now to examine the effect of jacketing, as shown in these trials.

It will be seen by referring to Table I that the engines were, with the exception of the alteration in the use of the jackets, under the same conditions in trials C, B and A; and that the steam consumption varied from the 16.64 pounds per indicated horse-power per hour, when all the jackets were in use, to 15.75, when all were shut off, it being intermediate, or 16.15 pounds, when the low-pressure jacket only was in use. Thus, the consumption due to main engines and jackets was reduced .89 pound per indicated horse-power per hour, or 5.3 per cent., in changing from condition C to condition A, and .49 pound per indicated horse-power per hour, or 2.9 per cent., from C to B.

In Table II trials G, C, D were under similar general conditions as in Table I, as regards the use of jacketing, except that the high-pressure jacket only was shut off in trial C. Trials C and D were carried out at an expansion of 10.4; trial G, which was at the end of the thirty-hours' contractors' trial, was made at 12.5 expansions. Hence, although G shows a slight advantage to the jackets, compared with C, yet to compare the results of this trial with those on Table I we will take C and D only. Here also there is a reduction of water consumption with jackets

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out of use, of .43 pound per indicated horse-power per hour, or 2.7 per cent., between C and D.

In Table III trials A, B and C are under the same general conditions of steam pressure and expansion, and only differ as regards the use of the jackets. Here again, although in a very slight degree, there is a reduction of water consumption when the jackets are shut off, viz: .06 to .08 pound of water per I.H.P. per hour, or rather less that ½ per cent.

Bringing these results together, the trials show approximately an increase of water consumption per indicated horse-power per hour through the use of jackets as applied therein of—

.9 pound, or 5.3 per cent., at 18,000 I.H.P.;
.4 pound, or 2.6 per cent., at 13,500 I.H.P.; and
.06 pound, or less than ½ per cent., at 3,600 I.H.P.

The points of difference in these trials, which would affect the relative efficiency of the use of steam jackets, are the revolutions and expansions, and it appears that with the comparatively low revolutions and high expansion used at 3,600 I.H.P., the influence of the jacketing on the efficiency of the steam practically balances the expenditure of heat in the jackets, and that at lower speeds and powers, such as obtain at the cruising speeds of a fleet, a gain would probably be shown by the use of the steam jacket. At the higher powers the tests appear to show that no gain in economy is obtained by steam jacketing as carried out in this vessel.

Next considering the effect of the links.

On the full-power series the setting was not altered, and, therefore, had no effect on the consumption.

In Table II trials D, F, B, E and A were carried out without the use of the steam jacket, and the results may be exhibited as follows:

	D.	F.	B.	E.	A.
Expansions	10.4	9.7	9.1	8.3	8.3
Pounds of water per I.H.P. per hour	15.44	15.36	15.97	16.22	15.73

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It will be noticed that trials A and E took place at the same ratio of expansion, the difference being in boiler pressures maintained.

In Table III the expansions vary from 15.7 in trial C to 8.3 in trial F, no jackets being in use in any of these trials. The consumptions are shown in the following table:

	C.	D.	E.	F.
Expansions	15.7	13.2	9.1	8.3
Pounds of water per I.H.P. per hour	16.26	16.68	17.58	17.72

And it will be seen that corresponding to a decrease in the expansion from 15.7 to 8.3 there is an increase of about 9 per cent. in the consumption.

The consumption of water for all auxiliary engines in use throughout the machinery department and the ship during the hours in which the evaporators were not in use was, relatively to the power of the main engines—

3.57 pounds per I.H.P., or about 22 per cent. of the consumption of main engines only on the trial at 3,600 I.H.P.

1.59 pounds per I.H.P., or about 10.4 per cent. of the consumption of main engines only on the trial at 13,500 I.H.P.

During the full-power trial the evaporators were in continuous use, and the amount of water passing through the auxiliary condenser was 44,651 pounds per hour. As the evaporators were worked compound, and the secondary steam was led through a distiller, the drainage water from the second evaporator, as well as the boiler steam used in the first evaporator, was included in this quantity. The amount of water made by the distillers was measured by tanks. Allowance being made on the basis of the results of separate experiments made on evaporators and distillers, by the same maker, it is estimated that the consumption of steam for all auxiliary engines (excluding evaporators) was 1.88 pounds per I.H.P. per hour, or about 11.9 per cent. of the consumption of the main engines only. This increase in consumption

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for auxiliaries over that at 13,500 I.H.P. was, no doubt, due to the fact that, while the auxiliary engines which had been used on the 13,500 I.H.P. trial were generally working at higher speeds corresponding to the higher power of the main engines, double the number of furnace air-blowing engines were in use, working at a considerably higher speed, besides eight fan engines, running at 150 revolutions per minute, which were in use on this trial only.

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REMINISCENCES OF EARLY MARINE STEAM ENGINE CONSTRUCTION AND STEAM NAVIGATION IN THE UNITED STATES OF AMERICA, FROM 1807 TO 1850 (CONTINUED).

By Charles H. Haswell, Esq.

[Read at the Fortieth Session of the Institution of Naval Architects, March 23, 1899.]

Having essayed in a previous paper to give some reminiscences of the construction and operation of early steam engines and of steam navigation in the United States, it is proper that any omissions in the recital given should be supplemented, in order that, as a record is undertaken, it should be made as full as knowledge and memory will permit.

John Stevens, of Hoboken, New Jersey, applied the parallel motion, invented by James Watt, of England, in 1784, to guide the piston rod of an overhead or beam engine in the steamboat *Phœnix;* in 1809 he patented slides and a crosshead to guide the piston rod, and in 1817 his son, Robert L. Stevens, applied a cut-off to an engine by a camboard, and in 1825 he applied slides and a crosshead to the engine of the steamboat *Trenton*, connecting the crosshead to the beam by a rod with bifurcated ends; which design, in a few years after, was improved by the use of two right-line rods, as now practiced.

Ferry boats, up to 1821, when the steamboat *Hoboken* was built, were constructed with twin hulls, a water wheel operating between them ; and, with the exception of one boat on the North and one on the East River, they were driven by horses, and up to 1829 were steered by a tiller directly, and, in the absence of an upper or awning deck, the helm was conned by a man on or at the side of a wheel house. The pilots of passenger boats, even those running hence to Albany, New Haven and Providence, were not protected from the weather otherwise than by a

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temporary shield leading from the deck to their waist. All iron and copper bolts, nuts and rivets were hand made, the bilge and injection pipes were of lead, and the injection and discharge pipes without any side or bottom valve.

In engines constructed prior to 1824, and even somewhat later, the steam and exhaust valves of condensing engines were so disproportionate to the volume of steam entering and exhausting, that it would be "wire-drawn" to an extent that generated a very discordant sound, professionally termed "squealing."

In 1822 Robert L. Stevens largely increased the steam valves by assigning to the single one-third the diameter of the cylinder, and to the double beat a combined equivalent area. These latter were first introduced by him, in 1830, in the engine of the steamboat *New Philadelphia.*

On the Hudson, Delaware and like rivers, the landing of passengers from a steamboat, when the number did not exceed the convenient capacity of a quarter boat, was effected by the launching of it, seating the passengers, and then by the attachment of a long line the boat was towed, and when the passengers were landed on the pier or bulkhead of the landing, the boat was drawn back to the steamboat by the line leading over a drum on a water-wheel shaft, the speed of the steamboat being but partly arrested during the time of the landing, and not at all afterwards.

1827.—It was not until this year that there was either a dry dock, or a marine railway, in or on which a vessel's bottom could be cleaned of barnacles, breamed or metalled. Consequently, when any one of such operations became necessary, the hold of the vessel was first discharged, and large blocks and falls were led from her tops to a pier or bulkhead at low water, and set taut. Then, as the tide rose, her outer side and bottom would be exposed, and the opportunity for all the operations required would be afforded.

1830.—Up to this period green sand castings were generally so very rough that hammering and pickling of their outer surfaces were necessary to remove the indurated or vitrified sand.

In 1837 a condensing steam engine was designed and con-

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structed in the United States Navy Yard, Brooklyn, having a cylinder 4 inches by 12 inches, with a horizontal fire tubular boiler, and water wheels 3.5 feet in diameter by 8 inches face, which was put in the gig of a sloop of war lengthened to 35 feet, and this was the first successful essay of the practical application of a steam engine to a launch. Speed, 8.5 miles per hour.*

1839.†—Francis B. Stevens, of Hoboken, N. J., designed the cutting off of steam by the addition of a second eccentric and rock shaft, and in 1840 successfully applied it to the steamboat *Albany*.

On May 20, 1842, Frederick E. Sickles, of New York, U. S., designed and patented an "Apparatus for lifting and regulating the closing of the valves of steam engines," a cut-off, termed and known as the "drop valve." The design was that of disengaging the stem of the steam valve (when vertical) at any assigned point of expansion of the steam, and the operation, whilst effective, was primarily attended with the difficulty of the arrest of the valve in its descent under the pressure of the steam bearing upon it, and of the moderating of the resulting impact of it in its seat; it was gradually and finally effected by the operation of a small piston in a closed cylinder, the confined air in it acting as a cushion. So perfect was the operation of this instrument, that in the construction of the engine of the U. S. steamer *Water Witch*, the throttle valve in the steam pipe was dispensed with, as the cut-off could be operated even at the initial point of the stroke of the piston.*

In 1842 Edwin A. Stevens, of Hoboken, New Jersey, designed, patented and operated a closed fire room in the steamboat *Rainbow*, supplied with air by a fan blower located externally, and in 1845 the system was introduced in the U. S. steamer *Mississippi*.‡

In 1842 Captain John Ericsson designed the application of screw propeller blades to the sides of a steamboat, like to a side wheel with diagonal blades, operating them with two independent

* Designed and directed by the writer.

† Illustrated in "Engineering" (London), February 18, 1898, p. 219.

‡ Under the direction of the writer.

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steam engines constructed for a high pressure and many revolutions. The result was not satisfactory, and the boilers were replaced with others of greater capacity, designed for a greater pressure. But the application of propeller blades was a disappointment; the engines and wheels were removed and replaced with an ordinary vertical beam engine and water wheels with radial blades.

In 1844 zinc was for the first time laid in the bottom of a vessel—in the U. S. propeller steamer *Legare*—with a view to arrest the oxidation of the plates by the consumption of the zinc, and so successfully did the application operate, that in 1847 it was applied to the boilers of the U. S. steamer *Princeton*.*

1844.—July 24. Henry R. Worthington, of New York, designed and patented the independent steam, fire and bilge pump (donkey), and in 1859 the duplex valve motor.

On July 22, 1846, Francis B. Stevens filed a caveat in the Patent Office at Washington, U. S., embracing his design of projecting atmospheric air under the wetted surface of the bottom of a vessel in motion, to diminish that portion of the resistance of a vessel commonly termed the friction of the wetted surface. In 1847, after experiments were made on the Delaware and Raritan canal by towing models and boats by a locomotive running on a track at its edge, a joint patent for the design was obtained by him and his uncle, Robert L. Stevens, in the United States, England and France; and in 1848 and 1849 they designed and directed the construction of the steamboat *John Neilson*, to which the elements of the patent were applied. In operation the application increased the speed of the vessel.

1848.—Frederick E. Sickles designed the first application of a steam engine to the rudder of a vessel, and successfully introduced it in operation.

* Designed and directed by the writer.

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THE STEAM TRIALS OF H. M. S. *AMPHITRITE*.

[Reprinted from "Engineering," April 14, 1899.]

The first-class cruiser *Amphitrite*, of 11,000 tons and 18,000 indicated horse-power, built and engined by Messrs. Vickers, Sons and Maxim, Limited, Barrow-in-Furness, underwent a series of steam trials in the English Channel in April, and these trials are specially interesting in view of the fact that arrangements were improvised so that the exhaust from the auxiliary machinery could be utilized in the evaporators for making up the feed, instead of being passed direct into the condenser. It was at one time intended to use the exhaust from the feed pumps to drive the circulating-pump engine, and subsequently for making up the feed, but the time available before the date fixed for the trials did not permit of the necessary alterations being made for both purposes. On the pipe between the auxiliaries and the condenser a loaded valve of the piston type was fitted to get a constant pressure in the exhaust pipe, which, of course, acted as a receiver, and the necessary connections were made from it to the evaporator. It was not considered desirable to subject the auxiliary engines to a higher back pressure than 20 pounds to 25 pounds (the pipes are tested to 50 pounds), and it was for this pressure that all the arrangements were made.

On the 3,600 indicated horse-power trial, it was found impossible to maintain this pressure in the pipe receiver, as the only engines exhausting into it were two of Weir's feed pumps, working at little more than three strokes per minute, and the fire and bilge pumps. The spring of the valve was, therefore, set at about 8 pounds load. Neither fans nor compressed-air blowing engines were in use in the stokehold at the low-power trial. Under these circumstances the experiment was discontinued after two hours, as it was found that the receiver pressure could only be maintained at 7 pounds, and as little steam was passing

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to the evaporator, the loss in the feed water—a little over 1 ton per hour—was not being made up. As measured at the feed tanks, the "make-up" was only slightly over ¼ ton per hour. Of course, the deficiency had subsequently to be made up, as it is a condition in the case of all naval steam trials that the loss during a trial must be made good, so that the reserve feed at the end will at least equal that at the beginning. Excepting about ½ ton, therefore, the loss in the 30 hours' trial was made up by using steam taken direct from the boiler, although for a considerable period the evaporators, as on some previous trials, were worked on the compound system, the steam passing at the point of exhaust from the one to the other of the two evaporators in the ship.

As to the results of the 3,600 indicated horse-power steaming trials, as given in the appended table, they must be pronounced as very satisfactory. The coal consumption—1.54 pounds per indicated horse-power per hour—is the lowest recorded in any trial with water-tube boilers. The fuel was certainly of good quality, the strong wind insuring good draft was an advantageous element, the system of stoking regularly and moderately was perfect; but, in addition, it must be said that the engines worked very smoothly, the adjustments being excellent, while care was taken to insure that the circulating water did not "drown" the small quantity of steam passing through the condenser, so that the feed was maintained at a fair temperature. Again, the boiler casings fitted well—a point not always attended to—and the pipes were more extensively lagged than in the *Diadem* class, there being eighteen instead of six tons of the coating material, so that the loss from radiation was minimized. The cylinder jackets were not used.

The power was very steady, with noticeable uniformity as between port and starboard engines, while it was arranged that the high, the intermediate and the two low-pressure cylinders combined would give equal proportions of power. The engines were set to cut off at about 30 per cent. of the stroke, the links being run full in. We give the mean results in tabular form; and, although we have described the *Amphitrite, Argo-*

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naut and *Ariadne*, all vessels of the same class, we may say that the engines have four cylinders—one of 34 inches, one of 55½ inches, and two of 64 inches diameter by 48 inches stroke. The high pressure and intermediate are placed as closely together as possible, the cranks being opposite, while the two low pressures similarly balance each other. The propellers are 17 feet in diameter, 21 feet pitch, with 63 square feet of developed blade surface in each. There are thirty Belleville boilers, the total heating surface in the tubes being 32,375 square feet, and in the economizer tubes 15,505 square feet, a total of 47,880 square feet, while the grate area is 1,390 square feet, the ratio being 1 to 34.4 of heating surface.

STEAM TRIALS.

Date of trial	April 8 and 9, 1899.	
Nature of trial	30 hours' coal consumption at 3,600 I.H.P.	
Draught of water, forward, feet and inches	24–9	
aft, feet and inches	26–6	
Speed of ship by log, knots per hour	12.8	
at measured distance run, knots	13.32	
Steam pressure in boilers, pounds per square inch	226	
at engines, starboard, pounds per square inch	212	
port, pounds per square inch	212	
	Starboard.	*Port.*
Vacuum in condensers, inches	26.3	26.9
Revolutions per minute	73.0	72.1
Mean pressure in receivers, high, pounds	134	138
intermediate, pounds	32	34
low, inches	1.5	1.8
Mean pressure in cylinders, high, pounds	38.7	35.8
intermediate, pounds	15.0	15.9
forward, low, pounds	5.56	5.46
aft, low, pounds	5.59	5.38
Mean indicated horse-power, high	621	568
intermediate	643	674
forward, low	317	308
aft, low	318	302
Total	1,899	1,852
Grand total	3,751	
Consumption of coal per indicated horse-power per hour, pounds.	1.54	
total, pounds.	173,324	

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On the 3,600 indicated horse-power trial, however, only twelve boilers were in use, those nearest the engines, and in view of the economy it may be said that the grate area in use totalled 588 square feet, so that the horse-power equalled 6.37 per square foot of grate, and the coal burnt was 9.84 pounds per square foot of grate per hour.

The *Amphitrite*, which was under the command of Captain G. L. Atkinson, Captain of the Chatham Steam Reserve, steamed out of the Medway on Saturday morning, having been delayed a day owing to the gale, and anchored in Plymouth Sound on Sunday evening. During the greater part of the time she experienced a strong head wind, which accounts for the log speed being 12.8 knots. On Sunday morning Commander Rollston took records of the speed on two runs over the measured deep-sea course between Rame Head and the Dodman. The weather conditions were suitable. There was a westerly wind of force 2.

On the first run, with this breeze dead against the ship, this distance was covered in 1 hour 42 minutes 7 seconds, equal to 13.51 knots; but there was a slight current with the ship. On the return run with the wind, but against the current, the time was 1 hour 45 minutes, equal to 13.14 knots, a mean of 13.32 knots, which agrees with the speed on the other ships of the class under similar conditions.

During the subsequent trials of the vessel the success first achieved was repeated. The coal consumption on the 13,500 indicated horse-power, or maximum continuous-steaming trial, was only 1.43 pounds per indicated horse-power per hour, which is the lowest point yet touched by a vessel with water-tube boilers, and we have no such record result taken with corresponding exactitude in a merchant steamer. The rate of consumption never varied much; only two of the hourly "chits," as they are called on board, noted a higher rate than 1½ pounds, one 1.55 pounds, and another 1.51 pounds. The stoking was done systematically and intelligently, with the minimum of coal and the maximum of distribution over the grate, and an arrangement was made whereby a door was not opened at more frequent intervals than 6½ minutes. Again, in "clinkering" the fires, the great bugbear

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of the engineer, only one-third of a grate was cleaned at a time, and the work in a stokehold with eight boilers was equally distributed over a watch.

The same system obtained on the full-power trial, but instead of the interval between stoking through each fire door being about 6½ minutes, it was reduced to about 5½ minutes, and the proportion of coal increased; but as Lieutenant Norton, of the United States Navy, said at the Institution of Naval Architects, when full power is wanted in action, no one cares what the consumption is. However, there is no reason why the *Amphitrite*, or any of the ships of the class, should not repeat their trial performance as regards coal consumption as well as power. Experience on board a succession of ships leads us to commend the steady improvement in the stoking. The men are "tumbling" to the requirements of the large-grate boiler as a consequence of their training. On the full-power trial of the *Amphitrite*, the consumption was 1.57 pounds per indicated horse-power, which must be pronounced a favorable result. As a matter of fact, she traveled at the rate of 518 nautical miles per day of 24 hours, for a total consumption of 305 tons; this for 11,000 tons displacement of ship is undoubtedly satisfactory.

An interesting point was that no compressed-air blowing engines were used throughout the trials, and, judging from the results obtained, it seems that if sufficient attention is given to the firing, blowing engines for supplying air jets in the furnaces are not necessary, saving steam, and weight and space in the stokeholds. This economy, too, has been partly confirmed in the evaporation trials on shore. Moreover, on the full-power trial only were the fans for supplying air to the stokeholds run, and even then they made but 100 revolutions or so per minute during the first 4½ hours, and about 150 revolutions in the remaining 3½ hours, when also the stokeholds were closed down; but no perceptible air pressure was produced. The diameter of the fans is 6 feet 6 inches. It is true that on the 13,500 indicated horse-power run the wind was of considerable force during the greater part of the trial, affording good draft.

In view of the economy which was attained, it may be stated

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that on the 3,600 indicated horse-power trial the auxiliary engines at work included the following: Two main circulating engines, one electric-light engine, two main feed pumps (the one averaging four to six double strokes per minute, and the other nine strokes), and two auxiliary circulating pumps, all for the 30 hours. One of the hot-well pumps was worked for 30 hours, the other for 3½ hours, there being a cross connection between the two; an evaporator pump was run for 18 and another for 21 hours, while one fire and bilge pump was used for 15 hours, a second for 20, and a third for 30 hours, and the steering engines and ash hoists were, of course, worked as required. On the 30 hours' 13,500 indicated horse-power trial, the two main circulating, the electric-engine, two auxiliary circulating, and two hot-well pumps were worked throughout; while the four main feed pumps were on for 21 hours, and the auxiliary feed pumps during the remainder of the trial, it being the Admiralty practice to run part of the trial with the main and part with the auxiliary pumps to test both. One evaporator was worked for 23 hours, and another for 15 hours. The four fire and bilge pumps were worked for 20 hours on an average. Two fans were tried for 2 hours at 90 revolutions. On the full-power trial all the fifteen auxiliary engines named were at work along with the eight fans.

As to the main propelling engines, they worked beautifully. The cut-offs in the 13,500 indicated horse-power trial were at 64 per cent. in the high-pressure, 65 per cent. in the intermediate, and 70 per cent. in the two low-pressure cylinders. On the full-power trial the cut-off in the high-pressure cylinder was at 66 per cent. of the stroke. It will be seen that the setting was arranged so that the high, intermediate, and the two low-pressure cylinders together, would give as near as possible the same proportion of power. The object of this arrangement is to insure a lower range of pressure and temperature in the low-pressure cylinder, and thus to reduce condensation. On each trial the feed water reserve had to be made up to the same level as at the beginning. On the low-power trial the effect of the working of the evaporators with steam taken direct from the boilers was marked, the rate of consumption going up about 0.15 pounds

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per horse-power hour. Two tons of distilled water per hour were then being made. As to the use of the exhaust of the auxiliary machinery for the evaporators, reference is made to it in another article in the present issue on the consumption of steam in auxiliary engines on warships, in connection with corresponding trials in the *Vindictive*. The main purpose of the *Amphitrite's* trials was to conform to the specification, and the improvised and somewhat hastily-prepared arrangements for the exta test somewhat affected the success of the experiment.

No trouble was experienced with the boilers. After the thirty hours' trial at 13,500 indicated horse-power, it was found that one square feed collector, which extends across the front of the boiler at the bottom of the elements of tubes, was slightly laminated; but we mention this only to show with what facility repairs or changes can be effected in the boilers. There was a spare feed collector, and it was substituted for the other, partly while the vessel was doing her gun and circle trials. Several of the fusible plugs, fitted in the junction boxes of the elements, came out during the full-power trial, probably due to the diameter being rather large.

The appended table gives the mean results including pressures in the receivers and cylinders, as well as the powers, for both 13,500 indicated horse-power and the full-power trials. On the first-named trial the power varied from 13,169 to 14,085, and at the eight hours' trial from 18,062, the rate for the first two hours, to 18,443 indicated horse-power, the aim being not to exceed the designed rate to any great extent.

The total weight of the machinery complete is 1,550 tons, and of boilers 757 tons, and it may be interesting to note that on the full-power run the power developed was equal to 24 units per ton of boilers, and to 11.7 indicated horse-power per ton of machinery. The fuel consumption was at the rate of 19.8 pounds per square foot of grate, and the power developed equalled 13.1 per square foot of grate, while the heating surface per unit of power is 2.62 square feet. It may be added that on the occasion of evaporative trials on shore with two of the boilers, the coal burnt per square foot of grate was at the rate of 30.38

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pounds per hour, and the water evaporated 9.37 pounds, the equivalent evaporation per pound of coal from and at 212 degrees Fahrenheit being 11.45 pounds. The steam pressure was 300 pounds. This trial was of four hours' duration.

RESULTS OF STEAM TRIALS.

	First trial.	*Second trial.*
Date of trial	April 12 and 13, 1899.	April 17, 1899.
Nature of trial	30 hours' coal consumption at 13,500 I.H.P.	8 hours' full power at 18,000 I.H.P.
Draught, forward, feet and inches,	24-3	24-3
Draught, aft, feet and inches	26-3	26-3
Speed of ship, nautical miles per hour	19.73 on measured course, 19.52 by log.	20.78 mean of four runs, 20.94 by log.
Steam pressure in boilers	252 pounds per square inch; reduced steam, 240 pounds.	279 pounds per square inch; reduced steam, 254 pounds.
Air pressure in stoke holds	*Nil.*	*Nil.*

	First trial.		Second trial.	
	Starboard.	Port.	Starboard.	Port.
Vacuum in condensers, inches	25.8	26.2	26.2	26.3
Revolutions per minute	111.6	110.6	122.4	121.2
Mean pressure in receivers, high, pounds	233	231	246	243
intermediate, pounds	77	76	87	91
low, inches	13.2	11.5	18	18
Mean pressure in cylinders, high, pounds	89.8	89.2	103	102.6
intermediate, pounds	36.2	36.4	44	44.3
forward low, pounds	13.2	13.1	17.2	16.6
aft low, pounds	13.5	13.2	16.8	17
Mean indicated horse-power, high	2,208	2,174	2,770	2,736
intermediate	2,364	2,355	3,155	3,147
forward low	1,149	1,130	1,638	1,569
aft low	1,177	1,138	1,608	1,606
Total	6,898	6,797	9,171	9,058
Grand total	13,695		18,229	
Consumption of coal per indicated horse-power per hour, pounds	1.43		1.57	
Total, pounds	228,360		587,760	

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HOURLY RECORD ON EIGHT HOURS' FULL-POWER TRIAL.

	Steam pressure.	Revolutions.		Indicated horse-power.			Consumption of coal in pounds.	
		Starboard.	Port.	Starboard.	Port.	Total.	Per hour.	Per I.H.P. per hour.
	Pounds							
1	279	120.8	120.6	9,033	9,029	18,062	31,680	1.75
2	280	121.4	120.9	9,032	9,030	18,062	32,640	1.81
3	282	122.1	120.8	9,162	8,951	18,113	29,040	1.60
4	280	123.0	121.4	9,286	9,022	18,308	26,640	1.46
5	277	122.3	120.9	9,181	9,152	18,333	28,080	1.53
6	276	123.6	122.0	9,318	9,125	18,443	29,520	1.60
7	280	122.6	121.1	9,169	9,095	18,264	29,040	1.59
8	277	123.2	121.9	9,186	9,063	18,249	21,720	1.19
Mean.....	279	122.4	121.2	9,171	9,058	18,229	28,545	1.57

We supplement our record of means by the subjoined table, giving the hourly records on the eight hours' full-power trial, the results showing the remarkable uniformity of the running of the main engine; it will be noticed that the variations between the starboard and port are almost within the limits of error. The coal consumption, as was to be expected, was rather high at the beginning of the trial; the men had not quite settled down to their work. It should also be stated that the evaporators made a large volume of water during the trial.

Stopping, starting and reversing trials were made on Saturday. With the steam gear the time taken from full speed ahead to stop was 39 seconds with the starboard, and 20 seconds with the port engine; from stop to full speed astern 8 seconds and 10 seconds respectively, and from full speed astern to full speed ahead 10 seconds with each engine. With the hand gear both engines were stopped in 1 minute and 36 seconds, and the complete change from astern to ahead was made in 65 seconds. The reversing gear is slightly different to that fitted in the *Niobe*, and is much more rapid in its action. In addition to that, on account of the defects which have been reported in connection with the working of the *Niobe*, the pipes supplying the receivers from the starting valves have been considerably increased in size. A series of trials were

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made in the *Amphitrite* with the engines in almost every possible position, and with the vacuum in the condenser purposely broken, in order to test the facility of handling. So far as could be ascertained during the trials, extending over two hours, there was no position in which the engines would not start almost immediately, either ahead or astern as required.

SPEED TRIALS OVER THE 23 KNOTS MEASURED COURSE.

APRIL 12, 1899. (13,500 INDICATED HORSE-POWER.)

Number of run.	Time for 23 miles.		Course.	Revolutions per minute.	Speed.	Slip.
	min.	*sec.*		*mean.*	*knots.*	*per ct.*
1	72	4	Dodman to Rame Head	112.4	19.15	17.8
2	70	24	Rame Head to Dodman	112.5	19.60	16.0
3	69	1	Dodman to Rame Head	112.9	20.0	14.6
4	74	47	Rame Head to Dodman	112.2	18.45	20.7
			Mean of means	112.5	19.55	16.2

APRIL 13, 1899. (13,500 INDICATED HORSE-POWER.)

5	72	48	Dodman to Rame Head	111.4	18.95	18.0
6	67	50	Rame Head to Dodman	113.5	20.34	13.6
7	70	42	Dodman to Rame Head	113.2	19.52	16.9
8	71	28	Rame Head to Dodman	111.4	19.30	16.5
			Mean of means	112.1	19.73	15.2

Mean of mean speed for Nos. 1 to 4 ..... 19.55 knots.
Mean of mean speed for Nos. 5 to 8 ..... 19.73 knots.
Mean of mean speed for Nos. 1 to 8 ..... 19.64 knots.

APRIL 17, 1899. (FULL POWER.)

1	67	41	Rame Head to Dodman	121.0	20.39	18.8
2	65	46	Dodman to Rame Head	122.6	20.98	17.5
3	66	46	Rame Head to Dodman	121.9	20.67	18.3
4	66	1	Dodman to Rame Head	122.7	20.9	17.9
			Mean of means	122.1	20.78	18.

As to the speed of the ship, eight runs were made over the measured course between the Dodman and Rame Head. On the 12th the weather conditions were most unfavorable, as will

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be seen by the results in the table appended. Although the revolutions on the four runs varied little, there was a great difference in the speeds recorded, and, consequently, in the slip of the propeller. There was a southwesterly wind, which steadily increased in violence, unduly increasing the third and decreasing the fourth run, when the wind was of force 6, so that the slip was high. Running 120 miles beyond the Scilly Isles, when a heavy sea and a high wind shook the ship up a bit, a young shark about 3 feet long came aboard with one of the seas over the forecastle. On the 13th the ship again ran the measured course, although the weather conditions were not much better; but for less revolutions than on the preceding day, the speed was 19.73 knots instead of 19.55 knots. The wind was from the N.N.W., and on the first two runs was of force 2, and on the third and fourth of force 4.

On the full-power trial the same course was run four times under favorable weather conditions, the sea being calm with a genial sunshine. On the first and third runs the southwest wind blowing (force 2 to 3) was against the ship, and on the first run there was also a slight current against the vessel. The mean speed recorded, it will be seen, is almost exactly that anticipated by the design, 20.75 knots for 18,000 indicated horse-power. The 20.78 knots was got with a mean of about 18,280 indicated horse-power.

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STEAM CONSUMPTION OF AUXILIARY ENGINES IN WARSHIPS.

[Reprinted from "Engineering," April 21, 1899.]

The use of higher steam pressures on our warships has, as was to be expected, given rise to a number of problems in the details of marine machinery of a more or less difficult character, and the profession is to be congratulated upon the energy and perseverance with which the search for solutions is being pursued. We have time and again pointed to the fact that such an advance as from 150 pounds and 180 pounds to 280 pounds and 300 pounds pressure necessarily involved the discovery of difficulties, for the road to success is obstructed by failures, and it is satisfactory to find Sir John Durston, the Engineer-in-Chief of the Navy, on the one hand, and the experienced engineers of the Admiralty contractors on the other hand, ready and anxious to conduct steam trials under various conditions in order to arrive at truth. We do not speak now of the boiler question, nor of the economy of the water-tube boiler. The latter may not be perfect—science knows no limitations; but it undoubtedly confers important advantages, tactical and otherwise. These advantages need not again be enumerated here, but in view of the recent accident on the *Terrible*, it may be as well to point out that it has never been claimed seriously that salt water can be used constantly, or for any great period of time, in the water-tube boiler of the Belleville type, or, indeed, of any other. The same remark applies to boilers of the cylindrical and all other types, and evaporators and distillers of ample capacity are provided on our vessels for making up the losses of feed water, which necessarily occur during regular work.

On steam trials the nitrate of silver test is applied to the feed water to determine if there is any leakage in the condenser, or any other possible sources of contamination with salt water, and

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the engineer of the ship in command is expected every watch to use his hydrometer for the same purpose, so that the presence of sea water may be detected. There have been cases before now of the auxiliary feed being opened from the sea to make up a shortage—doubtless, without the engineer's knowledge; and the wise precaution is now being taken to have no direct connection between feed pump and sea to the boilers, any sea water required being admitted in the engine rooms. This precaution will certainly be effective.

In one of the cruisers of the *Arrogant* type the bursting of three solid-drawn tubes was caused by deposit, probably due to the use of salt water, but these failures involved no damage, because the furnace doors were not opened. It may be noted that a failure of this kind is not so much a question of welded *vs.* solid-drawn tubes—although the latter are to be preferred—as of avoidance of deposit in the tubes. In the *Terrible* the saline density of the feed was, for some reason or other, four or five times that of sea water. But even if a tube gives way, there is usually some warning by the partial leakage of steam, and the commendable course is then to shut the stop valve and open the safety valve of that particular boiler; but certainly not to open up the furnace. If such action be taken, experience has shown that there is no danger to life or limb. But, in addition, it must be remembered that disasters due to a similar cause have befallen the cylindrical boiler, and such mishaps would occur with practically any form of boiler worked under a high pressure, if sea water were used for any lengthy period. Moreover, there is in the case of the cylindrical boiler no such easy means of averting danger, as indicated in connection with water-tube boilers, as, owing to the greater volume of water and steam contained in boilers of the former type, the opening of the safety valve has not the same immediate action as it has in the case of water-tube boilers.

But, as we have already hinted, our present purpose is to notice rather some of the machinery difficulties, which are discovering themselves at frequent intervals in connection with higher pressures, and to record the combined efforts of the Admiralty, and

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the contractor to overcome them. The experiments on the *Argonaut* constitute a case in point, and here it was determined that there was a loss resulting from the use of jackets in powers over about one-fourth of the maximum. On the trials of the *Amphitrite*, which are dealt with elsewhere, no jacket steam was used at any power. We hope soon to be able to supplement the *Argonaut's* results with some experience of jacketing and non-jacketing at one-tenth of the total power, and we shall then consider the whole matter further. But the general question of the consumption of fuel is still under consideration. It is true the *Amphitrite* has excelled in this respect over all previous ships, and the contractors, Messrs. Vickers, Sons and Maxim, Limited, have broken the record formerly established by their own ship, the *Niobe*. Good coal, efficient and economical engines and careful stoking, with the minimum of auxiliaries in use, largely explains the result. The aim, and we may add also the difficulty, of training stokers, is to prevent the men firing too vigorously. Three or four shovelfuls through each door every five or six minutes suffices, but the old system of filling the furnace full and then having a long rest has its fascinations for the stoker, although the new method is not nearly so exhausting.

It has been proved by water test on the *Argonaut* that the consumption of the auxiliary machinery is 22 per cent. of the total consumption with the main engines working at one-fifth power and 10.4 per cent. when the main engines are developing three-fourths power, but it would not reach such large percentages on the *Amphitrite*, as she had not the same number of auxiliary engines in use, there being no fans or compressed air blowing engines working. The water, however, was not weighed or measured during the *Amphitrite* trials, so that separate results cannot be given now. Experience, however, shows that the auxiliary engine steam consumption of the *Argonaut* was not by any means excessive for vessels of her class. In the cruisers *Arrogant* and *Furious*, second-class ships of 10,000 indicated horse-power, the auxiliary engine consumption at certain powers was from 35 to 50 per cent. of the total. This was ascertained in the *Arrogant* by using separate boilers for auxiliary purposes only, leaving the

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others for driving the main engines. The actual results are worth giving here. The trial was of thirty hours' duration, and was suitably divided so as to ascertain not only the relative consumption of the main and of auxiliary engines respectively, but also to arrive at the effect of various pressures and cut-offs in the high-pressure cylinder.

Period.	Steam pressure.	Cut-off in H.P. cylinders.	Indicated horse-power.	Coal for main engines.	Coal for auxiliary engines.
	pounds.	*per cent.*		*pounds.*	*pounds.*
First.....	155.5	51.3	2,096	2.34	0.45
Second.....	213.5	23.8	2,147	2.3	0.58
Third.....	225	23.8	2,086	2.02	1.06
Fourth.....	234	33.9	2,229	2.09	.82
Fifth.....	160	51.3	2,240	2.03	.78
Sixth.....	161.5	60	2,312	2.12	.8

In the first two periods the main feed engines, main circulating engines, furnace-blowing engines and hot-well pumps were worked from the boilers driving the main engine, and not separately, so that there seems a better economy from using a lower pressure of steam—155 pounds and 160 pounds—in the auxiliary machinery. Of course the coal for auxiliary purposes is given on the basis of the power developed by the main engines, and thus varies from about 40 to 50 per cent. of the total.

The efficient lagging of the hot surfaces was about the first point to which attention was turned, and a gain was attained by reducing the radiation from such surfaces, one of the constant losses. As we have pointed out already, the *Amphitrite* has eighteen tons of such lagging. Experience further showed that the loss from condensation and radiation was considerably reduced by working auxiliaries at from 150 to 200 pounds, instead of 300 pounds, and reducing valves are fitted in many cases to effect this object on the auxiliary as well as the main system. It is intended also to compound all the auxiliary engines, fire and bilge pumps; the circulators are already in many cases compounded, and all will be so in the future. The hot-well pumps will be compounded, as well as the auxiliary circulating

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pumps. The fan engines will not be compounded, as they are not often in use. Messrs. Weir, the makers of the well-known feed pumps, have under consideration the idea of working their pumps in series with other pumps. Mr. J. Weir, from his great experience, is not inclined to the view that a crank pump will be as efficient as the simple pump, or that a double pump can be worked expansively, owing to the great pressure that they have to overcome—550 pounds. However, one is being made for experiment, but it is not improbable that the methods now under consideration at the Admiralty for utilizing the exhaust steam will render any change in the feed pumps unnecessary.

One of the proposals is to utilize the exhaust steam from all auxiliaries for making up the loss in feed water, and this steam will also be passed into the low-pressure cylinder receiver. This is done in the merchant service; but there the speed is fairly constant from the time of starting to the end of a long voyage; whereas, as Kipling has put it, a "man-of-war must always have 2 or 3 knots up her sleeve in case the Admiral demands a spurt; she must also be ready to drop 3 or 4 knots at the wave of a flag, and on occasion she must lie still and meditate. This means a varying strain on all the mechanism and constant strain on the people who control it. I counted seven speeds on one watch, ranging from 8 to 17 knots." This variation is an element in the problem under consideration, as the inlet of steam to the low-pressure cylinder receiver would have to be regulated; but it is interesting to recall that Mr. McKechnie, now of the Barrow Works, thus utilized the exhaust steam in the case of the three belted cruisers he engined at Bilbao for the Spanish Navy five years ago, and no trouble was experienced.

The utilization of the exhaust from the auxiliaries for evaporators, however, offers a more promising improvement, and before describing what has been done in this direction, it may be stated that in the *Amphitrite* a back pressure was kept in the auxiliary exhaust system to ascertain the economy when thus worked, as compared with the usual conditions—260 pounds on the one side and a vacuum on the other. So far as observation went the altered conditions did not appreciably influence the economy.

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That was on the trial at 13,600 indicated horse-power, the results of which are given on another page of the present issue. After a few hours' trial under these conditions, the system for utilizing the exhaust for the evaporators was put into use. The installation was ordered for the *Amphitrite* at the last moment, and in view of the haste the arrangement was, perhaps not so carefully worked out as might otherwise have been the case. Two non-return piston valves were fitted in the auxiliary exhaust service as far aft in the system as circumstances permitted, and were controlled by a spring, so that the pressure on the forward side could be regulated. Forward of each valve a branch was taken to the evaporator to supply the usual coils, the pressure being maintained by the valve, which also served for escape, permitting direct passage to the auxiliary condenser in case of any sudden increase of pressure in the pipe. The vapor pipe from the evaporator was branched into the main condenser, so that the evaporator could be worked on a vacuum. It was hoped that with steam at 20 pounds pressure in the heating coils and 10 inch vacuum in the evaporator, there would be sufficient difference of temperature to allow the production of the necessary make-up in the ship. So far as could be seen while the apparatus was in use, the make-up obtained was very nearly, although not quite, that got from the evaporators when they were working compound. But the experiment on the 13,600 indicated horse-power run of thirty hours had to be brought to a conclusion on account of the giving out of the cover joint on one of the auxiliary air pumps. This involved the whole of the work being done by one auxiliary air pump, and as it was not deemed desirable by the Admiralty officials on board to interfere unduly with the contractors' trials, the experiment was discontinued.

This was more readily agreed to, probably, as in the cruiser *Vindictive* trials were being carried out exclusively to determine the efficiency of such an arrangement. Moreover, longer time was allowed for fitting apparatus, and the system made more perfect. What we may call the back-pressure valves were in this case placed at the auxiliary condenser, so as to deal with the steam from all the auxiliary engines. In the case of the *Amphi-*

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trite the exhaust steam for the steering, electric, and other machinery was not trapped, and thus, while on the 3,600 indicated horse-power trial only 7 pounds pressure could be got, and only 12 pounds on the 12,500 indicated horse-power trial, a pressure of 25 pounds was easily maintained on the *Vindictive*, the result being most satisfactory.

The results in both ships show that the arrangement is worth trying, but the evaporators may possibly require to be increased in capacity, and it may be that a vacuum will be dispensed with altogether in the auxiliary condenser system. The evaporators, at present, it is interesting to note, are proportioned in capacity according to the total power of the propelling engines, the precise ratio of surface being left with the makers. The steam pressure available for working the evaporators would, with the new arrangement, probably be 20 pounds to 30 pounds instead of 200 pounds as at present, and it remains to be seen what effect the increased surface thus rendered necessary will have on the size and weight of the evaporator plant. At present a first-class cruiser of 18,000 indicated horse-power has an evaporative capacity of 90 tons per 24 hours when working the evaporators separately, and 56 tons when using them compound. In the case of a second-class cruiser of 10,000 indicated horse power, the evaporative capacity amounts to 50 tons and 30 tons per hour under the two conditions named, and in a third-class cruiser of 7,000 indicated horse-power to 38 tons and 24 tons respectively. There seems a constant proportion of make-up required, irrespective of power developed; the amount is only partly proportionate to the power. Even if the engines are standing, water is being lost. In the *Amphitrite* the loss was about 1⅛ tons per hour at 3,600 indicated horse-power, 1½ tons per hour at 13,500, and considerably more at full power, the major portion being apparently a constant quantity, but a leakage was discovered subsequently in an escape valve on the hot-well pump, which probably led to a considerable part of the increased loss at full power.

Another factor in economy is the method of fitting piston rings. With the ordinary split rings it has been found that the steam gets behind the piston rings, and at the high pressure they

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were pressed out to such an extent that the cylinder walls were cut and worn too rapidly, the bore in one case, we believe, being increased ¼ inch in diameter in six weeks. Solid pistons were next tried, but they became wasteful, as, after a time, they allowed steam to pass. Sir John Durston has now adopted a restrained ring. It is a split ring which can only open to a certain extent. It consists of a solid carrier of cast iron, with two split rings of hard bronze, fitted with a lip or indent. A small clearance is allowed between the carrier and the split rings, so that the latter can expand, but not beyond the clearance allowed. In working it acts as an ordinary loose ring; but it very soon begins to wear the cylinder. The wearing effect steadily diminishes until a perfect fit is worked—usually at the point when there is still only very little clearance left for expansion. But if there should subsequently be leakage past the piston, a little can be scraped off the clearance to allow the ring to expand a little more. This arrangement is now being fitted to all pistons, whether in the main or in the auxiliary machinery. Piston valves are necessarily used in all auxiliaries, owing to the high steam pressure, and this enhances the importance of a satisfactory piston ring.

A word may be said, in conclusion, as to driving the auxiliaries by electric motors. On the general subject we have already written, and it need only be said that the ventilating fans, the capstans, and the ash hoists are to be run by electric power in some of the new ships, and boat hoists are to be worked by hydraulic power in some of the new battleships. And, further, it must be mentioned as significant that Weir's steam-feed pumps are being adopted in increasingly large numbers in electric stations, where, if anywhere, electric drive would be preferred to steam if wasteful.

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COMPARATIVE THERMAL EFFICIENCY OF STEAM ENGINES AND DIESEL MOTORS.

By E. D. Meier.

[Reprinted from the "Sibley Journal."]

In the January number of the "Sibley Journal" is found an instructive article by Professor R. H. Thurston, of Cornell University, concerning the thermal efficiency of steam engines. Professor Thurston refers to the diagram by Captain H. R. Sankey, Secretary of the British Institution of Civil Engineers, in which he compares the exceptionally economical Leavitt engine of the Louisville, Kentucky, Waterworks, with the performance which would be possible could the Rankine idea be reached. Rankine first proposed this ideal cycle on January 17, 1854, and Clausis describes the same cycle in 1856, quite independently of Rankine. In short, the Rankine cycle takes in all the usual activities of the steam engine, but takes account only of those losses which are in their very nature inseparable from the cycle. All those vexations and costly losses which even the best practice does not now nor ever can eliminate from the problem, and which may be classed under the general heads of "radiation" and "friction," are in this ideal cycle considered as non-existent. In Professor Thurston's paper the comparison is made on an equal output in effective work. This I have changed for the purpose of better comparison in this case, by beginning with an equal expenditure in heat units at the beginning of the cycle, thus showing the difference in the output, in place of in the original total expenditure of heat. For the careful elaboration of these diagrams, credit is due to Mr. A. J. Frith, M. E.

In the case of the Diesel engine I start also with the same total expenditure in heat, and trace the flow of this "broad river of heat" through the entire cycle, showing the losses as actually found from a number of tests made on a 20-horse-power Diesel

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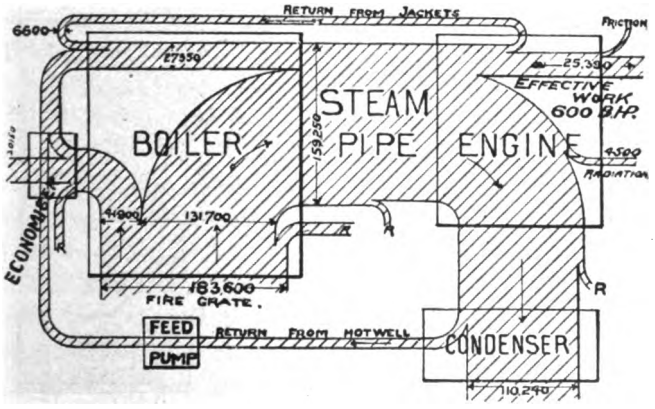
motor at New York. While there is every reason to believe that in a larger Diesel engine the losses both from radiation and from friction will show a smaller percentage of the total heat expended, still it would be unfair and unwise to bring into the illustration any merely theoretical deductions. It is better to show the facts as they are, and I content myself simply with pointing out that we are really comparing a 600-horse-power steam engine with a 20-horse-power Diesel motor. Every fair-minded engineer will concede that for a larger unit the advantage would be greater for the Diesel engine. It is but proper to remark that at the present writing no Diesel engine larger than 150-horse-power has yet been built, although units of 300 and 400 horse-power are now in process of designing. No special difficulties are apprehended, and the advice of such eminent authorities as Lord Kelvin and Professor Hartmann is in every way favorable to the larger units.

—Actual Steam Plant—

—Louisville Leavitt Pumping Engine—



The first diagram shows the reproduction of Captain Sankey's original graphic representation of the actual results obtained during the test of the Leavitt pumping engine at Louisville.

As Professor Thurston says: "This is a very exceptionally

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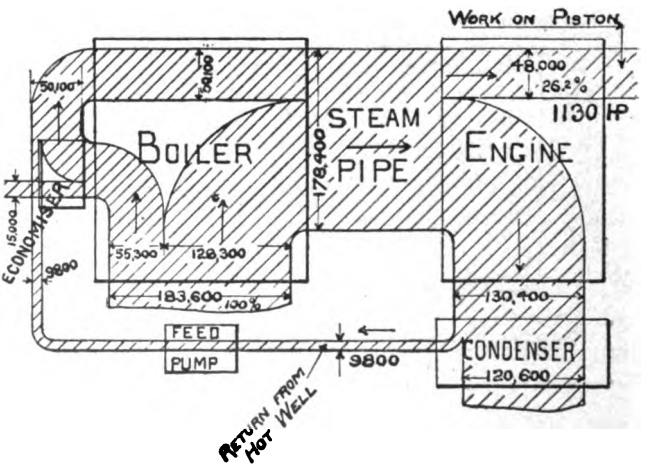
good illustration of thermo-dynamic action, and the wastes are very much smaller than are commonly observed in the operation of even good classes of steam engines."

The entire river of heat with a discharge of 183,600 heat units per minute flows from the fire grate. To the right is seen the loss by radiation in the boiler itself. But about three-fourths of the entire flow turns toward the steam pipe. Considerably over one-fifth, however, flows toward the left, toward the economizer, where it loses again by radiation, but is re-enforced by a brook coming from the hot well through the feed pump, and is further joined by a rivulet of returned heat from the jacket water, altogether forming a tributary of no mean size, joining the stream flowing into the steam pipe. Here again, at the bottom the small rivulet escapes through radiation, but the main body passes on into the engine, where we have the smaller losses by the stream which runs into the jackets, the other which represents the mechanical friction in the engine, and the third, the radiation.

RANKINE'S IDEALIZED STEAM PLANT



By far the larger stream, however, is lost in the exhaust steam. In passing through the condenser, however, a small brook is diverted toward the feed pump to again do useful work, as above

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described. We have then (in the upper right-hand corner of the diagram) left but the small fraction of 25,390 heat units, or say in effective work 600 brake horse-power, which represents only 13.83 per cent. of the total which is given to the engine; or, as it is customarily expressed, this most excellent engine plant, representing the highest development of modern steam engine practice, has realized an absolute efficiency of only 13.83 per cent.

The second diagram shows the same plant running on Rankine's ideal cycle. In this, friction and radiation are swept away by one happy stroke of the imagination. While a larger stream of heat is diverted to the economizer, this has become so effective that it allows only a small current to escape towards the chimney. In fact, this represents less than 8 per cent. of the original volume of flow. From the economizer a much larger stream, augmented by the brook flowing from the hot well, reenters the boiler, so that a total of 178,400 heat units enters the steam pipe, more than a quarter of which does useful work on the pistons. But the other three-fourths finds its way, as before, to the condenser.

In the stream which finally turns our wheels we find 48,000 heat units, giving us 1,130 H.P.; or the absolute efficiency of the Rankinized engine is 26.2 per cent. This, then, we may consider as the ideal possibility in steam engine practice, towards which we may strive but which never can be reached, because we cannot dispose of radiation and friction as easily as we have done on paper.

The third diagram shows Captain Sankey's method applied to the Diesel motor, with the same broad river of heat, having a constant flow of 183,600 B.T.U. per minute. The bulk of this enters the cylinder on its working stroke, but we have before lost more than thirty per cent. from three causes: The one is the actual negative work done in compressing the fresh air of the charge in the main cylinder, and which represents 30,700 B.T.U. A very small stream is the heat expended in compressing air in the air pump, and a third stream, aggregating 22,500 B.T.U., represents the loss by cooling, which flows into the jacket water during the period of compression. The two losses first mentioned flow back again into the cylinder during the period of combustion in the

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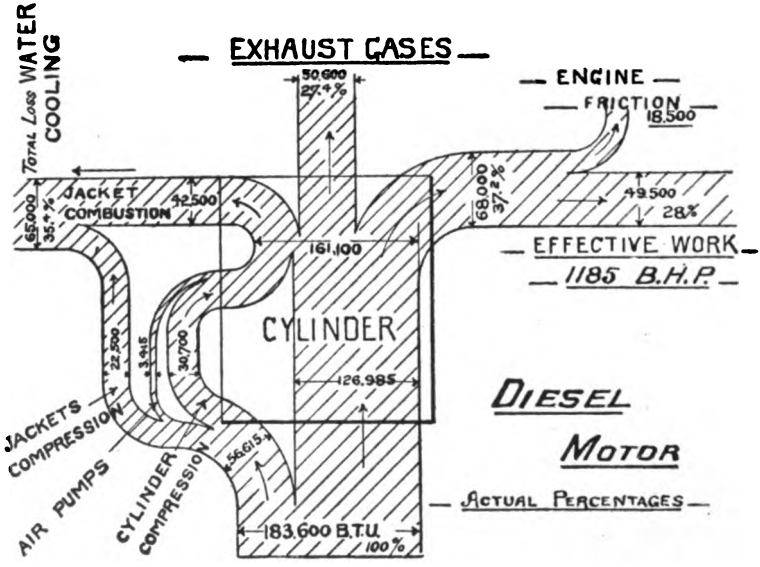
working stroke, so that we find their total at 161,100 B.T.U. But during combustion we lose again, as shown in the upper left-hand corner, a large stream of heat which flows into the cooling water of the jackets during this period of combustion, so that the final and total loss of heat which has flowed into this cooling water amounts to 35.4 per cent. of the total flow. Directly upward is shown a stream of heat amounting to 27.4 per cent. of the original flow, which we lose in the exhaust gases. To the right a good-sized stream, representing 37.2 per cent., flows into indicated work. From this, however, we lose a large amount,



viz: 18,500 B.T.U., in engine frictions. Comparing this with the loss shown in the first diagram of the Louisville engine, this stream looks very large. In explanation, however, we must remember that the steam engine has four effective or motor strokes to one in the Diesel engine. As the latter has to do its whole work in this one stroke, while the frictions retard it in the whole four strokes, it would be entitled to a percentage loss four times as great as that of the steam engine, without being subject to criticism as a mechanically inferior device. Furthermore, the

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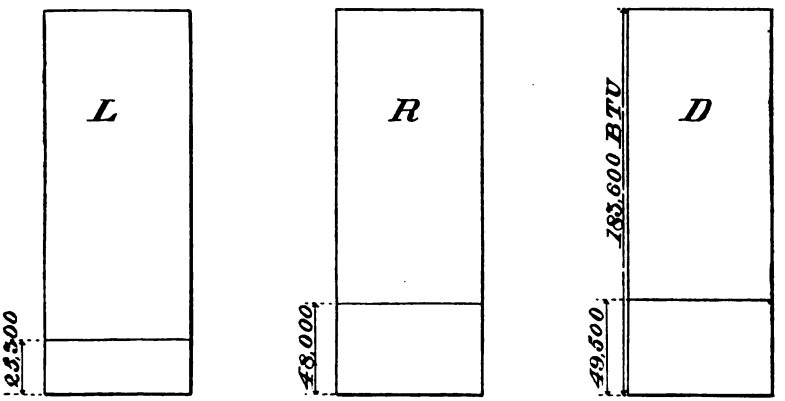
total stream of heat on which this percentage is to be figured is more than double as large as that which flows into the steam engine. If, then, this outflow in friction should appear eight times as large in actual quantity as that from the steam engine, it could not be considered abnormal.

Finally, we find a broad stream with a flow of 49,500 B.T.U. in the effective work of the engine, a total of 1,485 H.P., or the Diesel motor has shown 28 per cent. absolute proficiency. I must here remark that this 28 per cent. represents a fair average from a large number of tests, while I might have chosen an extreme case which shows over 30 per cent. But I prefer to illustrate in this manner results which we have very frequently obtained and feel confident of being able to reproduce and even to excel in all our engines.



The fourth diagram shows a comparison of the three engines, by a representation of areas simply. In each case the large rectangle represents the total of 183,600 B.T.U., with which each engine is charged. The smaller shaded portions of the three rectangles show in each case the return made. The rectangles are marked "L" for the Leavitt engine, "R" for the Rankine cycle and "D" for the Diesel motor. This shows at a glance that the Diesel motor has in actual practice far outstripped the theoretical possibilities of the steam engine.

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Turning again to the third diagram, let us examine where further savings can be effected in the Diesel motor. The engine frictions will no doubt be reduced in larger engines, and here is offered a good opportunity for the ingenuity of the designer and the skill of the mauufacturer, but after all the field is a rather limited one.

The next loss, that through the exhaust gases, can in many cases be very largely reduced by utilizing this heat for heating water or even producing steam for the heating of work rooms, or for various mechanical purposes. The largest loss, that shown toward the left, as the total loss to the cooling water, can also in many cases be utilized for the same purposes, and it is simply a question of temperatures and quantities whether these two streams are to be separately utilized or first combined.

These, however, are questions which can only be discussed here in a general manner, the solution in each case depending on the various local conditions of the problem. If, however, we may assume that in most cases we can utilize one-half of this waste, we would thereby nearly double the absolute efficiency of the entire plant. In a measure these collateral economies have the same right to be considered as those obtained from the economizer, condenser and steam jackets in the steam engine, and in this connection the Diesel engine has the comparative advantage that these streams of loss flow at higher temperatures, and can, therefore, in practice be more readily utilized.

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REMARKS ON THE INCREASING FREQUENCY OF FAILURE OF PROPELLER SHAFTS.

The following article from "The Steamship" calls attention, as have several other articles which have appeared in recent publications, to the question of propeller-shaft proportions and the causes of failure of this part of the machinery of steamships. The trend of the paper is to exhibit the comparatively light shafting given the economical leviathan tramp steamers of to-day; and while this undoubtedly conduces to disproportionate danger, and is wisely made prominent as a danger element, it has always appeared to us to be a graver fault that merchant steamship lines do not place a mileage limit on the tail shafting of their vessels, and after a certain number of thousands of miles have been made, replace these sections with spare in advance of any indications of distress. The removed section could probably be treated so that it would recover from its "fatigue" and be ready for efficient service when its turn again came.

With war ships, spare sections should be included in the original outfit, and would be a cost of small moment then. The irregularity of the voyages made by this class of vessels and the frequent and long periods spent at anchor, would make the safe limit, as far as the "fatigue" idea is concerned, incomparably longer than that of merchant-ship shafts; but spare sections are sometimes highly desirable to substitute for other reasons, and if the construction and installation of this part of the machinery is made with the view of a ready replacement, the original investment would soon be seen to have been wise.—Ed.

The loss of the *Westmeath* has aroused public attention to the alarming increase of frequency of accidents to the propeller shafting of steamers. Much is being said and written on the subject, and there appears to be a general consensus of opinion that something can be done, and must be done, to reduce this

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growing danger to life and property. The subject is many-sided and beset with difficulties, and it is one which seems to call very specially at the present time for ventilation and discussion by members of the Institution, who are more or less acquainted with its practical and theoretical bearings. No attempt will be made in this short paper to deal in detail with the various causes assigned by different persons for the frequency of such accidents; but a few general observations will be offered for the express purpose of provoking a discussion, which it is hoped may have good practical results. It is very likely that in the selection of the material of steamers' shafts, as well as in its forging and finishing, notwithstanding the extreme care usually exercised, still greater vigilance and more crucial tests might be applied to advantage. Or perhaps steel-drawn tubes may be adopted for shafting, in preference to iron-forged shafts, with some gain of strength and fitness. Or hydraulic-forged ingot steel, or Whitworth fluid-compressed ingot steel, may be preferably used for tail-end shafts.

The employment of hollow steel shafts of enlarged diameter between bearings, and of more widely spaced and fewer bearings than usual, may be increasingly resorted to. And it is, perhaps, not improbable that a means of running water through hollow steel shafts without corroding them may be found, in which case the water core would serve to keep the bearings cool, and at same time would greatly stiffen a thin, hollow shaft. It is also possible that further improvements might be made in methods for preventing the mischievous effects of corrosion and galvanic and chemical action on the outer skin of the shaft, and in the disposition of the shafting's supports and couplings, and generally in the details of their fittings throughout; for, though in these respects much has been done to attain perfection, no one will claim that perfection has been attained. It is indisputable that the commonest cause of accidents to shafts is the ship running light with propeller partly immersed. Indeed, this has been so long and so increasingly obvious, that serious suggestions have been and are being put forward to obtain legal powers to enforce observance of a limitation of lightness, as strictly as the

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limitation of loading is now enforced. Perhaps a more practicable proposal would be, that the Board of Trade should see that the shafts of steamers designed to run light as well as laden should be made stronger than for ships designed to run at a more nearly constant displacement. But whatever may be urged in support of superior forging and improved fittings of shafting, or in favor of limiting by law the lightness of the ship's draft, it does not seem evident, on the face of things, that there has been any recent change of practice in any one or all of these particulars, such as would account in an important degree for the remarkable recent increase in the number of accidents to propeller shafts. And yet it seems reasonable to conclude that there must be some particular cause for this increase; for it is hard to believe so marked a prevalence of a particular form of accident within the last year or two is due entirely to exceptionally bad weather or to merely fortuitous conditions absolutely beyond the control of shipmaster, shipowner, shipbuilder or enginebuilder.

Before we can adopt the conclusion that the frequency of shafting accidents in 1898 is no fault of anybody's, we should ask ourselves, Has there been any marked change in naval architecture and marine engineering during recent years which may have helped to bring about this frequent failure of propeller shafts? No sooner do we ask ourselves this question than we find confronting us the fact that during the last three years a most remarkable new development has shown itself increasingly in the British mercantile marine. This period of three years has been distinguished by the creation of a fleet of leviathan tramps such as were never seen in this world before. In building these monster cargo carriers shipowners have been keen, and very properly so, to turn to remunerative account a scientific principle specially familiar to everyone possessing even the most elementary knowledge of ship-model experiments. The principle is simply this: that for comparison of performance of ships of the same under-water shape, but of different sizes, corresponding speeds are proportional to the square root of linear dimensions, and corresponding powers are proportional to the displacement multiplied by the corresponding speed in each case.

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So that if the linear dimensions of one ship were n times those of another ship of the same under-water shape, the corresponding speed of the larger will be $\sqrt{n}$ times that of the smaller ship, and the corresponding power of the larger will be $n^3 \times \sqrt{n}$ times that of the smaller ship. Thus a ship of say 225 feet long, at a speed of say 10 knots, and a power $= P$, corresponds with a ship of the same under-water shape of say 450 feet long, at a speed of 14 knots, and a power $= 11.2\ P$. Now, to drive the larger ship at the same 10-knot speed as the smaller ship will take a power of only say $3.7\ P$. So that the larger ship with eight times the displacement can go at the same 10-knot speed with only 3.7 times the power of the smaller ship; thus the cost of power per mile ton of the larger ship is only $3.7 \div 8$, *i. e.*, less than half, that of the smaller ship at equal speed. Not only as regards power and consumption, but also as regards working expenses in many other ways, and also as regards first cost per ton deadweight, the principal of bigness proves its advantages.

Several firms of shipowners, a few years ago, realizing the commercial value of this principle, gave practical effect to it by building ships of the *Westmeath* class, which could be sailed at a profit when smaller ships were barely paying their way. And hence, throughout the last three or four years, ships of the leviathan tramp order have been coming more and more to the front, ships of enormous carrying capacity, and with very economical engine power. These ships have been engined to drive somewhat faster than the common tramp, but not so much faster as what would be the corresponding speed due to their great size; and so, while they have gained part of the advantage of their bigness by increase of speed, they have at the same time gained very considerably in economy of power and consumption.

Now it has become notorious that the casualties to ships through the breaking of their shafts are a much higher percentage of the comparatively small number of these leviathans than of other ships. In this fact the writer suggests some clue may be found as to the cause of the failures complained of.

Doubtless there are very many conditions and things combin-

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ing to determine the strength and endurance of a propeller shaft; indeed the subject, both on its practical and theoretical side, is almost inexhaustible. But, whatever other factors may govern, it is quite certain that, other things being equal, the strength depends to a very large extent on the diameter, and varies as some power of the diameter. When we come to ask, What power of the diameter? we are brought to consider the various kinds of stress to which a propeller shaft is subjected. Whether we regard it as resisting bending or as resisting tension, in both cases alike, its primal strength varies as the cube of the diameter. But stiffness, as affecting endurance, is a ruling quality to be considered as well as primal strength. Practically, in the case of very extended lengths of shafting, stiffness may in its effects be more important than the primal torsional strength. Referring to land engines, it may be said that a marked degree of flexibility in the shaft tends to irregular and erratic changes of stress, so that in land machinery stiffness of shafting is an acknowledged desideratum. But a steel ship of great length is endowed with a considerable degree of flexibility, and if the shafting be not equally flexible a quarreling of stresses must go on to the detriment of both the shaft and ship. It would, therefore, seem probable that what is wanted with a ship's shafting is not the maximum of stiffness so much as the maximum of harmony between the flexibility of the ship and her shaft.

Be that as it may, it is noteworthy that even with ordinary shafting of land engines the length of the shaft has a very effective influence on its real ultimate strength; for a shaft which, if short, might be quite strong enough to do the work required of it, might, for the lack of stiffness, fail if of great length.

It will be thus seen that the problem of how to determine the diameter of the shaft of a large steamer of the leviathan class is no easy matter, especially when it is recognized that we do not know how much or how little weight to attach to the question of stiffness of shaft as compared with primal strength. And this uncertainty may well influence our verdict as to what power of the diameter should be employed; for the stiffness of a shaft does not follow the same power as its primal strength; that is to

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say, the stiffness varies not as the cube, but as the fourth power of the shaft's diameter divided by its length.

One of the difficulties referred to at the opening of this paper is this difficulty of assessing the amount of play to be given to the principle of primal strength on the one hand and of elasticity and flexibility on the other.

In the realization of these difficulties we turn to the formulæ of the Board of Trade and Lloyd's, and the first thing we note is that by that authority the cube of diameter is adopted as the ruling power of the shaft's endurance, the question of stiffness being thus treated as though it were of no moment, or as though stiffness varied as the cube of diameter.

Now, if the ship were always running with the propeller well immersed, the question of stiffness might safely be neglected for two reasons: First, because the ship herself, having her stern water-borne, would not change her shape so much as when running light, and, like a cork on the surface, rolling and pitching and scending greatly in a seaway, and undergoing violent alternations of compression and tension; and, second, because the propeller itself when sufficiently immersed does not thrash the surface of the sea and subject itself and its shaft to the very damaging impactively irregular stresses which such thrashing occasions.

Doubtless if, without encountering mechanical objections which seem insuperable, ships' propellers could be easily adjusted to work always wholly immersed without reference to the ship's draught, considerable advantage would result not only by avoiding impact of the sea, so damaging to the propeller and shaft, but also by securing a higher and more constant efficiency of propulsive thrust. It is, however, to be feared that the practical difficulties besetting any plan for rendering the draught of propeller adjustable at pleasure will continue to prove in the future, as they have proved in the past, so great as to forbid such an improvement ever being commonly adopted.

While the greater length of shaft of a leviathan, as compared with that of an ordinary tramp, may, by its influence on the stiffness, contribute in some incalculable degree to the greater frequency of shaft failures in these leviathans than in ordinary

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steamers of the merchant class, there is in these mammoths surely some more palpably predisposing cause of shaft weakness.

Now the rules for determining the diameters of shafting adopted by Lloyd's and the Board of Trade make the strength of the shaft depend entirely on the power of the engines; and no separate account is taken in these rules of the power of the ship.

When the ship is steaming ahead in smooth water with propeller well immersed the power of the ship as developed in her resistance is the counterpart of the power of the engines as developed in their effective thrust on the shaft. So in that case, if the shaft has been proportioned of adequate diameter to withstand the thrust of the engines, it is likewise proportioned to withstand the resistance of the ship.

But when a ship is tossed up and down and set rolling by the waves a vertical power is developed by her mass, a power which the propeller has not to be held accountable for, as the propeller did not cause these waves. And yet, by this additional power the propeller is driven downwards or pulled upwards through the water besides being driven by the steam power. In some phases of the wave action this extra power will act on the propeller as a plus, and in other alternate phases as a minus stress, and thus the shafting will be subjected to more or less violent irregularities such as are known to be most prejudicial to the life of any material thus harassed and distressed. Now, this extra power of the rolling and pitching and scending ship in no substantial degree depends on the steam power driving the propeller, but is measured and determined by the inertia of the ship's displacement mass, and it is easy to understand that the enormous weight of a leviathan tramp thus proves too cruel to her comparatively small propeller shaft when it comes to a case of thrashing a stormy sea.

Probably if these big ships were driven at higher speeds corresponding to their bigness, and were thus furnished, as they then would be, with shafting of greater diameter agreeing with the greater driving power, according to the rules of Lloyd's and

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the Board of Trade, accidents to their shafting would occur not with more but with less frequency than in the case of smaller vessels, because the longer ship will prove the steadier in a seaway. But this advantage of additional sea steadiness seems in existing circumstances to be practically more than neutralized by the smallness of diameter of their propeller shafts, which, though proportioned to their comparatively small power of engines according to Lloyd's rule, are not proportioned as they ought to be to their huge displacement.

The writer, therefore, suggests that Lloyd's rule for the diameter of a steamer's shaft should be modified by implicating a coefficient expressing the power of the ship's displacement at her light draught.

Of course, any addition to the diameter of shafting must be attended by increase of cost, and, also, though not quite inevitably, by increase of friction.

So long as Lloyd's rule remains as it is, shipbuilders and enginebuilders, who have already in recent practice increased their shaft diameters for these large steamers beyond the requirements of that rule, will have to bear voluntarily the additional expense, and, doubtless, they will do so rather than run the risks which working by Lloyd's minimum entails in the cases of these monster ships. But it is undesirable in the interests of life and property that, in default of Lloyd's rule, the safe proportionment of shaft diameters should be left, even temporarily, to the discretion of shipbuilders and enginebuilders; and it is therefore to be hoped that an improvement in Lloyd's rule, which recent unhappy experiences have proved to be necessary, will be made at an early date.

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ELECTRICITY ON BOARD SHIPS.*

By S. Dana Greene.

[Reprinted from "The Electrical World," February, 1899.]

The modern first-class battleship requires about 2,000 indicated horse-power to drive all the auxiliaries at full load, and the first-class cruiser about 1,200 indicated horse-power. These auxiliaries, however, are never all in use at the same time, using maximum power, and it can be assumed that about one-half these amounts (*i. e.*, 1,000 indicated horse-power and 600 indicated horse-power) will be required at one time. They are scattered all over the ship, from the anchor hoist forward to the steering engine aft, and from the deck winches and boat cranes on the spar deck to the bilge and fire pumps in the engine and fire rooms, 30 or 40 feet below. Some of them, such as condenser, air, circulating, feed, bilge and fire pumps and fire-room blowers, are necessarily located within the engine and boiler-room compartments, where the temperatures are always high, and where steam, oil, water and coal dust are always present in greater or less quantities. Others, located on the spar deck, are exposed to salt water and air and to the varying conditions of sea and weather.

With these scattered locations it is obvious that power, generated at a central point, must be distributed throughout the ship. For this purpose there can be used either steam, hydraulics, compressed air or electricity. Hydraulics and compressed air not only have a low efficiency of conversion (from steam), but it is difficult to prevent leaks, freezing, bursting of pipes, etc. They have both been tried to a limited extent, and both found wanting in service. This leaves steam and electricity as the two remaining systems of distribution from which to choose. As between the two, steam has the following disadvantages:

* Synopsis of paper read before the American Institute of Electrical Engineers.

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First. Danger to life. The bursting of a steam pipe, whether in or out of a fight, is a serious matter, and likely to disable any of the crew who are in the compartment where the accident occurs. It has been abundantly proven in our civil war that men will not stand up against steam or hot water, when they will face shot and shell without flinching. Many of our vessels operating in inland waters during that war had several lines of hose coupled to a hot-water tank and led out every night to guard against boat attacks. These hoses were successful on more than one occasion in repelling boarding parties. While the main steam leads fore and aft can be run below the protective deck or behind the armor belt, vertical branches must run to all auxiliaries on the upper decks, and many of these must be used in action. The effect of a steam pipe carrying 100 pounds pressure bursting or being shot away in a compartment where there may be thirty or forty men at the guns or passing ammunition, would undoubtedly be to kill or disable every man in the neighborhood and demoralize thoroughly that part of the ship. On the other hand, if a wire is shot away, one or more auxiliaries may be disabled, but no one is injured; furthermore, the wire presents a much smaller target than a steam pipe, and is, therefore, less liable to injury from shot. It is always a difficult matter, too, to keep steam and exhaust pipes tight and to prevent leaks at the joints and at water-tight bulkheads.

Second. Injurious heating of living quarters. Steam and exhaust pipes must necessarily run to every auxiliary, and some of the latter, such as the ice machine, anchor hoist, steering engine, ventilators, etc., are in the officers' and men's quarters, or the pipes leading to them must pass through these quarters. The heat of the pipes and engines not only makes the quarters uncomfortable, but it is impossible to prevent more or less oil and dirt around the auxiliaries. In the tropics the heat is often so great that the officers and men cannot sleep below at all. This was the case on a number of our vessels operating in Cuban waters last summer.

Third. Efficiency. Here the contrast is very striking in favor

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of electricity, surprisingly so to one who has not seen the actual economy figures of steam auxiliaries.

There remain the two important factors of simplicity and reliability to be considered. No one who has had experience with the modern well-designed and well-insulated carbon-brush generator or motor can have any doubt as to its greater simplicity as compared with the steam engine. There are no joints to keep tight, no nuts or bolts to set up, no packing to renew, no cylinders to cut, and only two self-oiling bearings, as compared with a dozen or more oil cups on an engine. In fact, it is difficult to imagine a simpler piece of machinery than the modern dynamo. It seems like a return to elementary principles to discuss such a point; and yet many men aboard ship imagine the dynamo a most complicated affair, simply because they know nothing about electricity and think everything connected with it is mysterious and complex. This feeling is not confined to seafaring men, as we all know.

The question of reliability is a vital one, for no matter what the advantages with respect to safety, economy and simplicity may be, if the electric auxiliary cannot be relied upon at any and all times to do its work it is a failure and must be discarded. It must not only be able to work well under normal and favorable conditions, but it must also be able to stand a certain amount of abuse and neglect. Stress of weather and other conditions, particularly during a war, sometimes play havoc with the established routine of a ship, and the sailor's tools must not only be sound; they must be hardy. The normal conditions aboard ship are not favorable to ordinary electrical apparatus, but this simply means that apparatus for such work must be specially designed and built to meet these conditions. The ordinary motor would not last long under a street car; nevertheless thousands of car motors are built and sold every year which run day in and day out with a remarkably low maintenance account. Similarly, apparatus for ship work must be specially insulated, a larger margin of capacity must be allowed, and in exposed places it must be thoroughly enclosed. Several years ago an English manufacturer asked permission to install an electric deck winch on the

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spar deck of a new cruiser fitting out at Portsmouth. When the captain, who was superintending the fitting out of the ship, saw it he gave orders to have the deck hose turned on the motor for ten minutes, and then to operate the winch. The manufacturer protested, and said that the motor was not intended to be abused in that way. "Then take it off the ship," said the captain, "for I cannot guarantee that we will ship no seas during our cruise, and I want that winch ready for service whether we ship seas or not." The captain was quite right; the motor was taken off, and a "rough and ready," steam motor substituted.

Experience alone is the final test of reliability, and, fortunately, we have some experience in our Navy on which to rely. During the late war all of our regular war vessels were fitted with electric lighting plants, and many of the larger ships were supplied as well with certain electric auxiliaries, such as ventilating fans and ammunition hoists. Two of the *Brooklyn's* turrets were controlled by steam motors and two by electric motors. So far as I have been able to learn, from both official and unofficial sources, all the electrical apparatus on these ships stood the supreme tests of battle admirably, and the officers of the *Brooklyn* are enthusiastic over the performance of the electrically controlled turrets. They report that with respect to ease of manipulation and fineness of control there is no comparison, but rather a contrast. This is high praise from competent authority, for the officers referred to had actual command of the turrets in battle, and their judgment is not only unprejudiced and impartial—it is final and conclusive.

It is hardly necessary to say that electric machinery, to be reliable, must have reasonable care and attention from men who know something about it. The same is true of any machinery, and it is bad policy, as well as untrue, to say, as is sometimes said by those who should know better, that an electric motor requires no attention. Cleanliness is very necessary and may be considered as a first essential to successful operation. It is astonishing to see how little has to be done to an electric motor if it is kept scrupulously clean; but this cleaning must be regular and intelligent. From what has been said it may safely be affirmed

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that electric machinery can be made as reliable on shipboard as any other machinery, and with this in mind we can turn to the question of efficiency, including weight of plant and first cost.

There has been very little data published on the performance of ship auxiliaries, but a valuable contribution to the subject appeared in the February (1898) number of the "JOURNAL OF THE AMERICAN SOCIETY OF NAVAL ENGINEERS," by Passed Assistant Engineer W. W. White, United States Navy, entitled, "Steam Consumption of the Main and Auxiliary Machinery of the United States Cruiser *Minneapolis*." This vessel, as is generally known, is a first-class protected cruiser, of about 7,500 tons displacement, with three screws (each operated by its own engine) and a trial speed of over 23 knots per hour. She represents the highest type of her class, and is in every way a credit to her designers and builders. She has between thirty and forty steam auxiliaries, and more than 150 separate steam cylinders. Her only electric auxiliaries are the lighting generators and a few small ventilating sets and ammunition hoists. In order to ascertain the steam consumption of her main engines and auxiliaries Mr. White, who was serving on board the *Minneapolis* at the time as one of her engineers, made a series of careful observations during a run of the vessel of seven days from Gibraltar to League Island, Philadelphia. Indicator cards were taken on all auxiliaries fitted for the purpose (thirty-one in number), and the losses from leakage, condensation and radiation were carefully estimated, and the water evaporated carefully measured. The results obtained are certainly startling.

The average weight of steam used by the main engines per hour was 33,620 pounds, and by the auxiliaries 10,146 pounds. That is, the auxiliaries consumed nearly 25 per cent. of the total coal used. The main engines consumed an average of 20.83 pounds of steam per indicated horse-power per hour, and the auxiliaries an average of 119 pounds per indicated horse-power per hour (the lowest being 55.06 pounds and the highest 318.68 pounds per indicated horse-power per hour). These results are not exceptional; in fact, they are probably better than the average obtained on most warships or merchant vessels. The new

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British cruiser *Powerful* (14,000 tons displacement) is reported to have used 8,300 tons of coal from England to Hong Kong, of which 3,400 tons (or over 40 per cent.) were required for the auxiliaries.

Under the most favorable conditions the auxiliaries of a large ship probably consume at least 20 per cent. of the total coal and water used. This is more than twice as great as the consumption in a modern central station, and there is no good reason why as good results should not be obtained afloat as ashore.

Let us assume a required central-station capacity for a first-class battleship of 1,000 horse-power effective at the motors. The present standard e. m. f. for naval installations is 80 volts, and for the merchant marine about 100 volts. This low voltage was originally adopted on warships on account of the searchlights, which require 50 volts only, and it was desired to introduce as little dead resistance as possible. At this time no motors were, of course, in use, and the electric plant was used for lighting exclusively. Such a voltage is, however, entirely unsuited for a 1,000 horse-power plant. The weight of the distribution system would not only be excessive, but the size and weight of the generators would be prohibitive. The three-wire system, or a standard 220 to 2,250-volt two-wire system, should be adopted, using the necessary resistance in the searchlight circuits when they are in service; since they require a relatively small percentage of the total plant capacity, and are not regularly in use, this can be done without undue sacrifice.

The generating plant should consist of several units of the same size, so that parts are interchangeable, each unit consisting of a compound vertical engine driving a pair of generators or a single generator, depending upon whether a three-wire or a two-wire system is used. Assuming an efficiency of 82 per cent. for engine and generator, and an average line and motor efficiency of 80 per cent., the total efficiency of the system (between the indicated horse-power of the generating engines and the effective horse-power of motors) is 65.6 per cent. In other words, to develop 1,000 horse-power at the motors will require 1,500 indicated horse-power at the engines, or about 900-kilowatts genera-

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tor capacity. Six sets of 150 kilowatts each, with one reserve, would be required. A good compound engine working at approximately full load (and with six units those in actual service can always be operated at or near full load), will require 20 pounds of steam per indicated horse-power per hour. Assuming a total efficiency of the system of 65.6 per cent., as above, it will require about 30 pounds of steam per effective horse-power per hour at the motors. If we allow 25 per cent. margin for losses due to steam leakage, condensation, mechanical friction of gears, etc., we still have an economy of 37.5 pounds per horse-power per hour, as against 119 pounds as shown by the *Minneapolis* test. In this case the auxiliaries tested aggregated 471 horse-power developed, using 56,049 pounds of water per hour. At 8 pounds of water evaporated per pound of coal the coal consumption was 7,000 pounds per hour, or 84 tons per day, assuming that this power was required for twenty-four hours. If the water consumption had been at the rate of 37.5 pounds per indicated horse-power per hour, instead of 119 pounds, the coal used per day for these auxiliaries would have been 26.5 tons, a saving of 57.5 tons, or nearly 70 per cent.

It is fair to assume that by the introduction of compound engines and improved mechanical appliances on some of the auxiliaries the average steam consumption can, perhaps, be reduced to 75 pounds per horse-power per hour; but this is still 100 per cent. in excess of that required for the electric drive. Assuming an average daily use of 800 horse-power effective at the auxiliaries on a first-class battleship at sea, this difference in efficiency means a saving in water used of 360 tons per day, and in coal a saving of 45 tons per day. All steam cylinders connect with the condensers, so that the water used by the auxiliaries is not lost, but is used over and over again, it being necessary to supply only that lost by leakage in the pipes and condensers. The extra pumping duty is large, however. The coal saved, on the other hand, means that with a given coal endurance (or "steaming radius") a vessel can carry from 10 to 20 per cent. less coal; or, expressed in another way, with the same coal capacity she will have from 10 to 20 per cent. greater steaming radius. The average

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price paid in the Navy for coal (including stations in all parts of the world) is probably at least $7 per ton. There is, therefore, in the case assumed a direct saving in running expense of $315 per day for coal alone. It may be argued that a vessel in port does not use her auxiliaries to the same extent that she does at sea, and that, therefore, the comparisons made are misleading. This may be true as to actual savings in pounds of coal and water, or in dollars and cents, but the percentage differences hold true in any case. Furthermore, a ship is built to keep the sea, and her efficiency and usefulness are measured by her performance at sea, and not when incidentally or accidentally in port. Her weights are distributed and apportioned, and her power, speed and "steaming radius" are designed for sea conditions, and it is these conditions alone which should be considered.

The weight and space required for plant are important matters, for a modern steamship, and particularly a war vessel, has every available inch of space and pound of weight carefully allotted; and it is sometimes difficult for the designers to adjust the conflicting elements (which may be equally important) so as to provide for all and still keep within the prescribed limits. The present weight of steam auxiliaries of a first-class battleship, assuming a total capacity at full load of 2,000 horse power is, as before, about 200,000 pounds, or 100 tons. If the electric drive is used, we must add the weight of generating plant. The Navy specifications limit this weight at present to one-third pound per watt rated capacity. With 1,050-kilowatt capacity (six units of 150 kilowatts for service and one for spare) the weight would be 350,000 pounds, or 175 tons. The electric auxiliaries would weigh about the same as steam, or 100 tons, a total of 275 tons as against 100 tons for steam drive. There would be some saving in the wiring, as against steam and exhaust pipes, so that it may be assumed that the electric plant, with the generating sets described, will weigh between two and one-half and three times the steam drive. As an offset, however, we have the saving of 10 to 20 per cent. in coal required for a given steaming radius, which in a ship of this class would amount to between 200 and 400 tons. Furthermore, if in the future a satisfactory steam

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turbine comparable in economy with the compound engine is developed for marine work, as now seems probable, the weight of the generating plant will be reduced 40 or 50 per cent., and then the electric drive will compare favorably in this respect with steam, and there will still be the saving in weight of coal required for a given endurance.

The space necessary for plant must be considered as one of the vital parts of the ship, and as such it must be located below the protective deck. At first thought it may be said that it will be difficult to find the necessary space, but it must be remembered that the space required for 200 to 400 tons of coal is available, in addition to the space at present allotted for dynamo room, and these combined will certainly be more than sufficient.

The application of the electric drive to the various ship auxiliaries must be carefully studied in each case. The problems involved, however, are not more difficult than many special applications on shore, nor is there anything about them which a competent electrical engineer, with a proper knowledge of sea conditions, is unable to solve. The first cost will undoubtedly be greater than with the steam drive, but the savings in "operating expense," if capitalized, will much more than offset this difference in first cost.

The problem is purely an engineering one, and should be approached in a businesslike way. Will the electric drive be equally safe, simple and reliable, and will it be more efficient than the present system of steam drive? This is the question in a nutshell, and I believe that the figures and data which I have presented enable us to answer it most emphatically in the affirmative. Other nations, particularly England, Germany and France, have already introduced the electric drive extensively on their ships, both in the navy and in the merchant marine; and it is earnestly to be hoped that our own Navy, with its magnificent ships, officers and men, of whose record we are justly proud, will not lag behind in this important respect.

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THE EQUIPMENT OF TALL OFFICE BUILDINGS IN NEW YORK CITY.

By Reginald Pelham Bolton, New York City.*

In a space in the lower part of New York City, one mile in length and two-thirds of a mile in average breadth, there are at present located some fifty-six buildings exceeding 180 feet in height, while a few of these range from 200 to 325 feet from the sidewalk level. The demand for office accommodation in this district began in the vicinity of the Stock Exchange, and has developed buildings up the line of Broadway and parallel streets as far north as Franklin street and as far south as Bowling Green. The convenience of the various exchanges has grouped the different professions and contributing trades in certain districts, and the legal profession has been attracted to the district around the municipal buildings and the courts in City Hall Park.

While at first, when there were few such examples, they returned a fairly profitable investment without much regard to economy of operation, yet in recent years the construction of so many great buildings has brought about a sharp competition, which has called attention to economical equipment and operation, and has directed the attention of engineers to the problems which they offer.

Cost of Land.—The cost of desirably located sites has been of recent years greatly on the increase, and in certain advantageous positions has reached as high a figure as $300 per square foot. The corner plot on which the German-American (fifteen-story) Building stands, 111 feet on Liberty street and 79 feet 2 inches on Nassau street, cost $937,000, or about $110 per square foot, previous to the projection of the new building, and was later on purchased for the site of the present tall building at $140 per square foot.

* Read at the May meeting of the American Society of Mechanical Engineers.

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The land on which the Hudson (sixteen-story) Building stands, facing 45 feet on lower Broadway, extending 225 feet to New street, was purchased some years ago for an average rate of $65 per square foot, and would, for the purpose of the present increased building, be worth more than double that amount. An average value of sites for such buildings as are under discussion would now be $150 per square foot. A recent purchase of 1,736 square feet of ground by the Stock Exchange on Broad street is at the rate of $244 per square foot, while an extreme was reached by the price of $330 per square foot paid in 1882 for a very desirable corner site in the same neighborhood.

Increased Returns.—Such large amounts as these values represent naturally call for a large return from the building occupying the site, such return being obtainable in the old five and six-story buildings only by means of increased rentals. High rentals had, however, the reflex effect of driving tenants to less advantageous locations in rear streets until the height attainable in the modern buildings effected a combination of improved accommodation at a reasonable price. The effect of the above natural causes has been, therefore, even with a greatly enhanced cost of the site, a reduction in renting charges proportioned to the increase in rentable area. The competition between the various buildings has brought the minimum rate down from $3 per square foot to below $2 per square foot of office space, and includes in this charge light, heat, attendance, cleaning and, of course, elevator service.

Relative Increase.—It may be roughly estimated that the increased height of the down-town buildings referred to has added to the inhabitable area not less than 7,500,000 square feet. Illustrating the relative increase of value obtained by height, the four and five-story buildings occupying the site of the present German-American Building represented a renting area of not more than 6,000 square feet per floor, which at the old rates of about $3 per square foot per annum may have produced a gross rental of as much as $70,000 per annum when filled, but even this represented only 6 per cent. on the real value of the land alone. The new building has a net renting area of about 7,000

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square feet per floor, producing on fourteen upper floors, even at the low average of $1.60 per square foot, $156,000, in addition to which are two large ground-floor banking parlors producing about $17,000 and $12,000 per annum, respectively, also a basement restaurant bringing in $3,000, or a gross return of $188,000 per annum, an increase of two and a half times as much as the old buildings. On a cost for building and equipment of $650,000, and of land $937,000, or $1,587,000 in all, a gross return of nearly 12 per cent. is thus attained. The cost of management, operation of equipment, and city taxes naturally form a large increase on the same items in old buildings, but under good management and economy do not exceed 50 per cent. of the gross rental. It will be evident that the economical operation of the equipment forms a decided factor in the net balance available for interest.

As a mortgage can be placed on such a building and land for six-tenths of its value at a rate not exceeding 4 per cent. the net return on the actual capital sunk in such a building may be very high, nevertheless wasteful appliances and accompanying cost of management reduce the return in many instances down to 3 per cent. Once such buildings with moderate rentals and greatly increased advantages are established, they form a strong incentive to the erection of other buildings of similar or superior character owing to gradual abandonment of the older buildings by tenants, in favor of those where they find better conditions. The sanitary appliances in the older buildings were and are extremely behind the times, and have in numerous cases been the cause of tenants' removal. The old three and four-story buildings on the site of Bowling Green Building, from the above causes, became unremunerative and some were closed up to avoid taxation. The site, which fronts 157 feet on Broadway, extends 170 feet through to Greenwich street, and was valued at a million dollars by the building company. On this site the Bowling Green Offices have been erected, which is the largest commercial office building in New York City, being 240 feet 6 inches average height from street levels, and of a gross content of 4,915,000 cubic feet, with a floor area of 20,555 square feet on fifteen upper

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floors, and of 32,000 square feet on the ground floor and first basement, the sub-basement being devoted to mechanical services and storage. In this instance the increase in acreage has been enormous, the original 80,000 being raised to 567,500 square feet, or fully four times greater renting area than before. The total cost of the building was close on to two million dollars, and owing to the remarkable economy of its equipment and management it has been able to pay its way when not more than five-eighths occupied.

Size of Buildings.—The best method of comparison of size is that afforded by bulk. Representative instances are the following:

The Bowling Green Offices, sixteen stories above street, 235 feet high, 5,000,000 cubic feet gross contents.

New York Life Building—partly insurance—sixteen stories, 4,800,000 cubic feet.

Manhattan Life Building—partly insurance—seventeen stories and tower, 270 feet high, 1,665,000 cubic feet.

Lords Court Building—offices—220 feet high, 3,000,000 cubic feet.

American Surety Building—partly insurance—twenty-one stories, 305 feet high, 2,176,000 cubic feet.

These represent either abnormal height or bulk, and of them the Bowling Green and Lords Court Buildings are those built on a strictly commercial basis.

The representative commercial office building now averages 200 feet high, and of these there are now a large number.

Average samples are:

The Central Bank Building, sixteen stories, 1,980,000 cubic feet.

The German-American Building, fifteen stories, 1,400,000 cubic feet.

The Hudson Building, sixteen stories, 1,500,000 cubic feet.

R. G. Dun Building, fifteen stories, 1,200,000 cubic feet.

The above buildings also afford an opportunity for interesting comparison on account of the dissimilarity of their elevator systems—

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	Boilers.
1. Bowling Green Offices, nine hydraulic elevators	720 horse-power.
2. Lords Court Building, five electric elevators	420 horse-power.
3. Central Bank Building, five hydraulic elevators	460 horse power.
4. German American, five electric elevators	320 horse-power.
5. Hudson Building, four hydraulic elevators	500 horse-power.
6. R. G. Dun Building, six electric elevators	600 horse-power.

All of the above have been equipped to the plans of the author, and are, with the exception of the last, heated by the Webster system of vacuum returns with exhaust steam at atmospheric pressure.

The boiler capacity includes, in all but the last instance, a spare or reserve boiler. The R. G. Dun Building has a single-pipe back-pressure system of steam heat, and has only two boilers, both being in use in extreme weather.

The services provided in each are:

1. Car-miles per hour, 14 to 20;	lights, 6,200	Bolton vertical system of wiring.
2. Car-miles per hour, 9½;	lights, 4,000	Bolton vertical system of wiring.
3. Car-miles per hour, 11;	lights, 3,800	Bolton vertical system of wiring.
4. Car-miles per hour, 11;	lights, 2,800	Horizontal wiring.
5. Car-miles per hour, 8;	lights, 3,000	Horizontal wiring.
6. Car-miles per hour, 16;	lights, 4,500	Horizontal wiring.

Total Cost.—The cost of average steel-framed sixteen-story office buildings complete with equipment and inclusive of a moderate amount of decorative outside treatment in stone, machine mouldings or in terra cotta, without hand stone carving is 36 to 40 cents per cubic foot of its gross cubic content, outside measurement. The excessively high buildings cost more, also those with expensive adornments. The relative cost of the mechanical appliances, including power, elevators, heat, light and sanitation, is approximately one-seventh of above. The total cost of mechanical appliances in a building of sixteen stories, basement and sub-basement, say 6,000 square feet renting area per floor, was $82,000.

Or in detail:

	Cost.
Chimney	$1,200 to $2,500
Boiler plant	9,000 to 11,000
Four to six-elevator plant	28,000 to 40,000
Heating appliances and piping	14,000 to 17,000
Electric wiring and switchboard	9,000 to 15,000
Engines and generators	8,000 to 10,000
Sanitation and fixtures	12,000 to 15,000

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The effect of an increase in the cost of these appliances, if the same be productive of economy and advantage in operation, is very much less in proportion than its importance to the owner. For instance, the difference in the above comparative costs would amount to $26,000, say 4½ per cent. on gross cost of building, which would represent fully 50 per cent. more convenience and the best appliances for economy throughout. It has, however, been difficult at times to induce owners to spend on economical appliances a small fraction of the sum laid out on non-remunerative outside or interior adornment.

The difference between a compound and a triple-expansion pump may be say $1,500 and be begrudged, while the difference between marble trim and other substitutes in the hall will be $15,000 and be freely expended.

These are difficulties met by engineers everywhere, yet in no case do they appear so forcibly. It is satisfactory to relate that such instances have been rather due to the present faulty system of letting general contracts inclusive of machinery than to the owners' shortsightedness as regards the advantage offered.

Equipment.—The value of office buildings to the business community is based on the improvements they offer, which are chiefly of a mechanical character, and further examination of the requirements will make it evident that the importance of the mechanical equipment considerably outweighs the value of any architectural features.

The details of direct interest to mechanical engineering science in these great buildings may be grouped as follows:

The character and arrangement of mechanical plants.

Elevator service and the limitation of the height of buildings by the proportions of same.

Piping and connections.

The power plant, chimneys, coal supply, feed heating and waste heat.

Heating, ventilation and refrigeration.

Fire protection and water supply.

Electric lighting, wiring, generators and storage batteries. Telephone and electrical services.

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It will be obvious on a moment's thought that each one of these subdivisions is of sufficient importance, if treated with any fullness, to exceed the limits of a single paper. It is the object of the author at present to refer briefly to some of the problems connected with the arrangement of the mechanical plant of such an office building, as determined by the usual conditions which are prescribed.

Location of Piers, Etc.—The author's remarks are not intended to comprehend the details of the framing or building construction of these tall buildings, except in so far as they relate to the mechanical equipment required to operate them, but a brief *résumé* is necessary of the features of New York practice in respect of pier and foundation construction which bear on the subject of the arrangement of the plant.

The lower portion of New York City is composed of rock and sand, the rock being very irregular in outline, but roughly composing a ridge or hump on the line of Broadway, often dropping off abruptly. The sand is the floor of the glacial river beds east and west, and is firm and affords a good foundation. At the extreme end of the promontory and along the west shore there is a good deal of made ground, but only one of the tall buildings with which the author has been associated trenched upon this, and in that case was carried below its level. Where the sand overlays the rock in a shelving form, the foundations are carried to the rock, but a number of buildings exceeding 200 feet in height have had their columns set on isolated concrete piers laid on the sandbed.

Such piers are usually six feet square at the base, are two to four feet thick; on top is set the shoe of the column upon a plate about four feet square.

The columns forming the walls are similarly treated, but the piers are usually united by a footing of concrete on which the curtain walls are run up. These piers have to be avoided in arranging foundations for machinery or in laying subsoil piping.

In one instance, that of the German-American Building, where the foundation was on sand, the Chicago method was followed, of spreading the bases over the entire area by a gridiron of

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I-beams, the lower series extending to a width of eleven feet, making the location of machinery a very difficult problem.

In the Bowling Green Building many of the columns could have been set on the bare rock, on the northern half of the building, but the concrete blocks were required by the regulation of the Department of Buildings, and the rock was blasted out for the purpose. The rock shelved off towards the Hudson, and degenerated into a conglomerate, which proved to be watery, reaching to the original shore of the river within historic times, where made ground began. The natural water level is above the sub-basement.

In the Hudson Building, just across Broadway, the same depth of excavation did not expose the rock, and piles were driven about twenty to thirty feet through sandy clay to bedrock, the water level standing about two feet below the sub-basement level.

The method of support of this building, which was designed by Mr. Henry Hoge, Member American Society of Civil Engineers, consisted of a concrete bed formed on the pile tops, standing on which are exposed plate girders, five feet deep, across the sub-basement, on which the columns stand. Within the spaces thus formed the plant had to be arranged, which was accomplished as shown in the accompanying plan.

In the Lord's Court Building there is no sub-basement, but advantage was taken of the difference in level between the street and the Lord's Court at the rear to afford air and light to engine and boiler rooms. This building is carried on brick piers under each column in the usual manner. In all buildings the columns and bases are cased in with fire-proof brick or terra-cotta.

Space.—The general practice now provides a sub-basement for the purposes of the plant, providing much more space than could be afforded nearer the street. Yet such are the demands of business that even sub-basement space is valuable, and cannot altogether be devoted to the engineer. Such sub-basements are also very difficult places to provide with air and light, for which a very early demand must be made, if they are to be secured. The height generally is not less than ten feet, which, however is insufficient for water-tube boilers; therefore, the fire

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room is usually excavated to a further depth, exposing the bases of columns and frequently going below the water line.

In laying out the arrangements the guiding consideration is to so locate the boilers that the fire room will have a natural supply of light and air, and shall be readily accessible from the engine room. The author has departed in each instance from the practice of placing the boilers under the sidewalk, and has preferred even so long a flue as that in the Bowling Green Building, which is two hundred and forty feet in length, to a less advantageous position for the fire room. It must be recorded that the location of the chimney is usually fixed beforehand by the architect.

The disposition of the main engines and pumps is chiefly decided by the position of the foundations of columns, and the necessity of access and repair. The arrangement of auxiliary pumps is such that they shall be so readily reached by the fireman that it shall be unnecessary for the engineer to stand by them at all times.

This also enables the engineer, at certain hours of light duty, to attend to the firing.

The relative position of the coal storage to the fire room is of less consequence than its proportions. The fireman may easily attend to his own coal passing if provided with a track. But unless the coal storage is large, a coal trimmer must be kept to receive the daily supply. Trimming in the store costs, in certain buildings, five to fifteen cents per ton. Such a large storage as the Bowling Green, which can contain 420 tons, has been found of advantage in reducing the price of fuel about ten cents per ton, as it is not required to be delivered at any particular hour.

Buildings on Broadway are not permitted to receive coal or remove ashes and paper during certain hours, and consequently have to pay more for each convenience. The cost of removal of ashes under such conditions is sixty-five cents per truckload; but where the ash cans can be taken at any time, as on a rear street, the city removes without cost.

Labor.—A considerable variety and extent of labor is required

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in office buildings, and may be reduced by carefully planned arrangements and appliances.

The general superintendence is commonly delegated to a renting agent, who is paid by a percentage of three to five per cent. on the rentals received. The actual duty of superintendence then falls on an employee who has, generally, a number of such buildings in charge, which are therefore largely left to the mercy of the janitors. A better method is followed in some buildings by the addition of the duty to that of the chief engineer, when much closer supervision over details of operation is possible.

The rates of wages per week are as follows in an average sixteen-story building:

One janitor, without residence		$15.00
One doorman, or hall porter	$10.00 to	12.00
One car starter, with uniform	12.00 to	14.00
Four to six elevator boys, with uniform	10.00 to	12.00
Three window cleaners	8.00 to	10.00
One toilet cleaner	8.00 to	10.00
Twenty to thirty scrubwomen (5 to 9 P. M., 6 to 9 A. M.),	6.00 to	8.00
One watchman		10.00

and the following in the engineering department:

One chief engineer	$25.00 to	$31.50
One assistant engineer	20.00 to	22.00
One electric-elevator man		20.00
One electrician	18.00 to	20.00
One night engineer		15.00
One leading fireman		16.00
One assistant, or night fireman	13.00 to	14.00
One coal passer and ashman		12.00
One oiler		12.00

City Ordinances.—The chief engineer must carry a police certificate, and the assistant engineers generally do so, while some work on a fireman's certificate. Firemen's certificates are issued by the Police Department after an oral examination by the Chief Inspector of Boilers.

This Department has power to inspect and test boilers operating over ten pounds pressure per square inch, and to issue firemen's licenses for same.

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Inspection is rarely exercised, and the test is simply the hydrostatic application of double working pressure. The inspectors have no authority to deal with improper settings, proportions or connections, but do usually require, where more than one boiler are set in battery, two separate stop valves to each boiler, with a drip between the two, without which they decline to make the test.

The Department of Buildings has power to prevent the operation of any electrical power plant which does not comply with their electrical regulations, for which they issue an operating license to the owner.

The Departments of Health and of Buildings have excellent regulations regarding sanitary appliances, but the Health ordinance respecting the exclusion of steam and vapor from the sewers is constantly violated.

It is remarkable that the only trade employed in these large buildings which is subject to no regulation or supervision by authority is that of steamfitting. With the sole exception of a building requirement as to the protection of pipes concealed in proximity to woodwork, no demand can be made on them by authority, notwithstanding the numerous accidents which have been caused by faulty steam piping.

Another matter demanding extension of authority is the discharge of heated air on sidewalks from the engine and boiler rooms of office buildings.

Street Supplies.—There are in New York extensive purveyors of electricity, both direct and alternating currents, and steam under pressure.

The latter extends over the greater portion of the down-town district. All, as well as gas and water, naturally demand consideration as to their use in operating plants.

The author, in comparing cost of these supplies with the expected results of an independent plant, has found, at existing prices, the advantage to be in favor of the latter.

Steam.—The steam supply is provided over the down-town portion of the city at a pressure of seventy pounds per square inch, while an economical use can be made in these buildings of

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100 or 120 pounds pressure. The price of the steam supply is proportioned on the extent of its use, yet on largest and lowest basis it is in excess of the cost or local generation of steam. The case may be the reverse in smaller buildings, chiefly by reason of an economy in labor, but in the large office buildings a staff of men is necessary for maintenance and emergency work, and the wages of one fireman only represents about 16 per cent. of the full bill in an average building.

The New York Steam Company have abandoned their attempt to regain the condensed water from these buildings, their efforts having proved futile with their past apparatus. Consequently, their steam is raised under less favorable conditions than is the case in the large buildings.

It would seem that successful extension of this steam supply in future largely depends on the adoption of the modern methods by which this desirable feature can be assured, and their prices of steam thereby reduced. The difficulty of disposal of the hot condensed water from the large buildings is an objection to the use of this service.

Gas.—At the present price of $1.10 per thousand cubic feet of gas, a brake horse-power-hour can be obtained by a gas engine for a cost of two cents. This is certainly a low figure, and one that enters very closely into competition with steam. There are, however, certain disadvantages in the use of gas engines for these large buildings, which have hitherto deterred the author from their adoption. The great size of the units required is one, the liability to noise and to vibration is another. As the machines would be situated in the basement, the least vaporous smell of gas would be promptly objected to by tenants.

The question of irregularity of motion in lighting work can, no doubt, be disposed of by combination with a storage battery.

The same remarks apply to the use of the petroleum engine, which, however, is at present limited to units of not exceeding 50 effective horse-power. With these economical machines one brake horse-power can be obtained, at present prices of oil, for one cent per hour.

Electricity.—The electric supply of the illuminating companies

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forms the most serious competitor with an independent plant. At present prices for power the nominal rate is ten cents per horse-power-hour by meter, and users of large quantities can scale this rate down to as low as four cents per electrical horse-power-hour on a use of 10,000 horse-power-hours per annum, with a still further reduction of about one-half cent if a storage battery be adopted.

But, although the offer is of a temptingly simple and apparently advantageous character, a still further reduction in rates is required before the supply can compete with the results of a really economical independent plant. This reduction is probable, and, in combination with the storage battery and electric pumping for hydraulic elevators, the question will have to be reconsidered in the future. The charges must, of course, be increased by the cost of maintenance and interest on cost of the battery.

At the time of the establishment of the Bowling Green Building a careful computation showed, at the net price for lighting current of 8 cents per kilowatt-hour, including lamp renewals, and at the then price for elevator power of 7 cents per kilowatt-hour, an advantage in favor of an independent plant exceeding $5,000 per annum. The results of operation have shown a still larger advantage, as the plant was debited with the services of an engine-room staff of nine men, whereas it is now operated by only five hands.

The item which largely operates in this comparison is the utilization of exhaust steam in house heating for the 100 or 120 days of cold weather.

The cost of a horse-power-hour for power, oil and repairs, generated by an independent plant, may be, with economic arrangements, as low as $2\frac{4}{10}$ cents, and a fair figure, inclusive of interest and depreciation, is $2\frac{8}{10}$ cents; adding one-half share of all engineering labor, which is more than its due, a covering figure is $3\frac{8}{10}$ cents.

The installation of an independent plant has, so far, been decided by these considerations and by its relative superior economy. In future it is quite possible that this economy will

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be on the other side, but the use of such plants will, nevertheless, probably continue on the ground of the desirability of independence of outside supplies.

Such an argument recently received forcible illustration when the entire steam supply of the New York Steam Company was cut off by the action of a Water Department foreman, in turning off a valve in the main, the steam heat, elevators and lights of upwards of four hundred buildings being cut off from 3 P. M. to 9 P. M., causing most serious disorganization and loss.

The above considerations are those which lead up to and affect the decision to employ and install an independent plant in office buildings, such as those described in this paper.

Discussion.

The discussion of this paper *in extenso* cannot be given in this number, but after reading the next paper, "The Central Heating Plant of the University of Wisconsin," a general discussion of the central plant idea was obtained with reference to both papers, and later the President, through Mr. Robison, invited expression of the views of the members regarding the advantages or disadvantages of a central station for power, lighting and heating at large navy yards such as the New York yard.

In this discussion considerable stress was laid upon the importance of avoiding the central-station *craze* and being misled by generalities. It was pretty clearly shown that the economies that might be secured by a central plant arrangement are not such as should alone govern decision. Accident to a central plant involved possible stoppage of work which far outweighed the lesser cost of unit output.

The question of *heating* buildings distant from the central station was a grave one. It cannot be done economically by electricity, nor can exhaust steam be utilized at great distances. Transmission of live steam might be possible without serious loss if suitable tunnels for the piping could be built and radiation

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losses reduced to a minimum by having the warm air from the tunnel drawn out by fans and delivered under the grate bars of the boilers. This is not feasible in the New York yard, owing to tide-water level; besides it is not ideal altogether.

If live steam could be thus delivered from a central-boiler plant, the electric power could be developed in each shop, and the exhaust steam from these dynamo engines used to heat the buildings. Where economy of output from a central plant might be considerable at full load, it would frequently happen that the plant would have to run far below this rating and at a loss.

Considering all the views expressed, it appears to be the concensus of opinion that a single central-power plant for a scattered group of buildings is far from wise, especially where the requirements of some of the distant shops may be great, and where it would be not uncommon to have to run the central plant simply for *one* of the group at times when particular demand was thus made. Also the heating question involved requirements which are not properly satisfied by the central-plant arrangement.

Briefly, the trend of the discussion was to modify enthusiasm in the advocacy of central-plant stations, and to strongly bring out such real objections as would create conservatism, at least, in considering the question under all circumstances. As to a navy yard plant, with its attendant peculiar conditions, the weight of the arguments was against a central-plant installation. As with many other questions where a theoretical advantage, especially in point of economy of cost, appears certain, practical difficulties are found which are far out of proportion to the advantages.

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NOTES.

THE PERSONNEL BILL.

As the most important legislation of the last session of Congress, as far as Naval Engineers are concerned, was the passing of the *Personnel Bill*, there is no more fitting place for the record of its provisions than in the pages of this JOURNAL.

An Act to reorganize and increase the efficiency of the personnel of the Navy and Marine Corps of the United States.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the officers constituting the Engineer Corps of the Navy be, and are hereby, transferred to the line of the Navy, and shall be commissioned accordingly.

SEC. 2. That engineer officers holding the relative rank of captain, commander, and lieutenant-commander shall take rank in the line of the Navy according to the dates at which they attained such relative rank. Engineer officers graduated from the Naval Academy from eighteen hundred and sixty-eight to eighteen hundred and seventy-six, both years inclusive, shall take rank in the line next after the officers in the line who graduated from the Naval Academy in the same year with them: *Provided*, That when the date of a line officer's commission as captain, commander, or lieutenant-commander and the date when the engineer officer attained the same relative rank of captain, commander, or lieutenant-commander are the same, the engineer officer shall take rank after such line officer.

SEC. 3. That engineer officers who completed their Naval Academy course of four years from eighteen hundred and seventy-eight to eighteen hundred and eighty, both inclusive, shall take rank in the line as determined by the Academic Board under the Department's instructions of December first, eighteen

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hundred and ninety-seven; and engineer officers who completed their Naval Academy course of four years in eighteen hundred and eighty-one and eighteen hundred and eighty-two shall take rank in the line as determined by the merit roll of graduating classes at the conclusion of the six years' course, June, eighteen hundred and eighty-three and eighteen hundred and eighty-four: *Provided*, That those engineer officers who were appointed from civil life, and whose status is not fixed by section two of this Act, shall take rank with other line officers according to the dates of their first commissions, respectively: *And provided further*, That the engineer officers who completed their Naval Academy course of four years in eighteen hundred and eighty-one and eighteen hundred and-eighty-two shall retain among themselves the same relative standing as shown on the Navy Register at the date of the passage of this Act.

SEC. 4. That engineer officers transferred to the line who are below the rank of commander, and extending down to, but not including, the first engineer who entered the Naval Academy as cadet midshipman, shall perform sea or shore duty, and such duty shall be such as is performed by engineers in the Navy: *Provided*, That any officer described in this section may, upon his own application, made within six months after the passage of this Act, be assigned to the general duties of the line, if he pass the examination now provided by law as preliminary to promotion to the grade he then holds, failure to pass not to displace such officer from the list of officers for sea or shore duty such as is performed by engineers in the Navy.

SEC. 5. That engineer officers transferred to the line to perform engineer duty only who rank as, or above, commander, or who subsequently attain such rank, shall perform shore duty only.

SEC. 6. That all engineer officers not provided for in sections four and five transferred to the line shall perform the duties now performed by line officers of the same grade: *Provided*, That after a period of two years subsequent to the passage of this Act they shall be required to pass the examinations now provided by law as preliminary to promotion to the grade they then hold,

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and subject to existing law governing examinations for promotions.

SEC. 7. That the active list of line of the Navy, as constituted by section one of this Act, shall be composed of eighteen rear-admirals, seventy captains, one hundred and twelve commanders, one hundred and seventy lieutenant commanders, three hundred lieutenants, and not more than a total of three hundred and fifty lieutenants (junior grade) and ensigns: *Provided*, That each rear-admiral embraced in the nine lower numbers of that grade shall receive the same pay and allowance as are now allowed a brigadier-general in the Army. Officers, after performing three years' service in the grade of ensign, shall, after passing the examinations now required by law, be eligible to promotion to the grade of lieutenant (junior grade): *Provided*, That when the office of chief of bureau is filled by an officer below the rank of rear-admiral, said officer shall, while holding said office, have the rank of rear-admiral and receive the same pay and allowance as are now allowed a brigadier-general in the Army: *And provided further*, That nothing contained in this section shall be construed to prevent the retirement of officers who now have the rank or relative rank of commodore with the rank and pay of that grade: *And provided further*, That all sections of the Revised Statutes which, in defining the rank of officers or positions in the Navy, contain the words "the relative rank of" are hereby amended so as to read "the rank of," but officers whose rank is so defined shall not be entitled, in virtue of their rank to command in the line or in other staff corps. Neither shall this Act be construed as changing the titles of officers in the staff corps of the Navy. No appointments shall be made of civil engineers in the Navy on the active list under section fourteen hundred and thirteen of the Revised Statutes in excess of the present number, twenty-one.

SEC. 8. That officers of the line in the grades of captain, commander and lieutenant-commander may, by official application to the Secretary of the Navy, have their names placed on a list which shall be known as the list of "Applicants for voluntary retirement," and when at the end of any fiscal year the average vacan-

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cies for the fiscal years subsequent to the passage of this Act above the grade of commander has been less than thirteen, above the grade of lieutenant-commander less than twenty, above the grade of lieutenant less than twenty-nine, and above the grade of lieutenant (junior grade) less than forty, the President may, in the order of the rank of the applicants, place a sufficient number on the retired list with the rank and three-fourths the sea pay of the next higher grade, as now existing, including the grade of commodore, to cause the aforesaid vacancies for the fiscal year then being considered.

SEC. 9. That should it be found at the end of any fiscal year that the retirements pursuant to the provisions of law now in force, the voluntary retirements provided for in this Act, and casualties are not sufficient to cause the average vacancies enumerated in section eight of this Act, the Secretary of the Navy shall, on or about the first day of June, convene a board of five rear-admirals, and shall place at its disposal the service and medical records on file in the Navy Department of all the officers in the grades of captain, commander, lieutenant-commander and lieutenant. The board shall then select, as soon as practicable after the first day of July, a sufficient number of officers from the before-mentioned grades, as constituted on the thirtieth day of June of that year, to cause the average vacancies enumerated in section eight of this Act. Each member of said board shall swear, or affirm, that he will, without prejudice or partiality, and having in view solely the special fitness of officers and the efficiency of the naval service, perform the duties imposed upon him by this Act. Its finding, which shall be in writing, signed by all the members, not less than four governing, shall be transmitted to the President, who shall thereupon, by order, make the transfers of such officers to the retired list as are selected by the board: *Provided*, That not more than five captains, four commanders, four lieutenant-commanders, and two lieutenants are so retired in any one year. The promotions to fill the vacancies thus created shall date from the thirtieth day of June of the current year: *And provided further*, That any officer retired under the provisions of this section shall be retired with the rank

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and three-fourths the sea pay of the next higher grade, including the grade of commodore, which is retained on the retired list for this purpose.

SEC. 10. That of the naval constructors five shall have the rank of captain, five of commander, and all others that of lieutenant-commander or lieutenant. Assistant naval constructors shall have the rank of lieutenant or lieutenant (junior grade). Assistant naval constructors shall be promoted to the grade of naval constructor after not less than eight or more than fourteen years' service as assistant naval constructor: *Provided*, That the whole number of naval constructors and assistant naval constructors on the active list shall not exceed forty in all.

SEC. 11. That any officer of the Navy, with a creditable record, who served during the civil war, shall, when retired, be retired with the rank and three-fourths the sea pay of the next higher grade.

SEC. 12. That boatswains, gunners, carpenters, and sailmakers shall after ten years from date of warrant be commissioned chief boatswains, chief gunners, chief carpenters, and chief sailmakers, to rank with but after ensign: *Provided*, That the chief boatswains, chief gunners, chief carpenters, and chief sailmakers shall on promotion have the same pay and allowances as are now allowed a second lieutenant in the Marine Corps: *Provided*, That the pay of boatswains, gunners, carpenters, and sailmakers shall be the same as that now allowed by law: *Provided further*, That nothing in this Act shall give additional rights to quarters on board ship or to command, and that immediately after the passage of this Act boatswains, gunners, carpenters, and sailmakers, who have served in the Navy as such for fifteen years, shall be commissioned in accordance with the provisions of this section, and thereafter no warrant officer shall be promoted until he shall have passed an examination before a board of chief boatswains, chief gunners, chief carpenters, and chief sailmakers, in accordance with regulations prescribed by the Secretary of the Navy.

SEC. 13. That, after June thirtieth, eighteen hundred and ninety-nine, commissioned officers of the line of the Navy and of the Medical and Pay Corps shall receive the same pay and allow-

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ances, except for forage, as are or may be provided by or in pursuance of law for the officers of corresponding rank in the Army: *Provided*, That such officers when on shore shall receive the allowances, but fifteen per centum less pay than when on sea duty; but this provision shall not apply to warrant officers commissioned under section twelve of this Act: *Provided further*, That when naval officers are detailed for shore duty beyond seas they shall receive the same pay and allowances as are or may be provided by or in pursuance of law for officers of the Army detailed for duty in similar places: *Provided further*, That naval chaplains, who do not possess relative rank, shall have the rank of lieutenant in the Navy; and that all officers, including warrant officers, who have been or may be appointed to the Navy from civil life shall, on the date of appointment, be credited, for computing their pay, with five years' service. And all provisions of law authorizing the distribution among captors of the whole or any portion of the proceeds of vessels, or any property hereafter captured, condemned as prize, or providing for the payment of bounty for the sinking or destruction of vessels of the enemy hereafter occurring in time of war, are hereby repealed: *And provided further*, That no provision of this Act shall operate to reduce the present pay of any commissioned officer now in the Navy; and in any case in which the pay of such an officer would otherwise be reduced he shall continue to receive pay according to existing law: *And provided further*, That nothing in this act shall operate to increase or reduce the pay of any officer now on the retired list of the Navy.

SEC. 14. That upon the passage of this Act the Secretary of the Navy shall appoint a board for the examination of men for the position of warrant machinists, one hundred of whom are hereby authorized. The said examination shall be open, first, to all machinists by trade, of good record in the naval service, and if a sufficient number of machinists from the Navy are not found duly qualified, then any machinist of good character, not above thirty years of age, in civil life, shall be eligible for such examination and appointment to fill the remaining vacancies. All subsequent vacancies in the list of warrant machinists shall be

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filled by competitive examination before a board ordered by the Secretary of the Navy, and open to all machinists by trade who are in the Navy, and machinists of good character, not above thirty years of age, in civil life, authorized by the Secretary of the Navy to appear before said board, and, where candidates from civil life and from the naval service possess equal qualifications, the preference shall be given to those from the naval service.

SEC. 15. That the pay of warrant machinists shall be the same as that of warrant officers, and they shall be retired under the provisions of existing law for warrant officers. Warrant machinists shall receive at first an acting appointment, which may be made permanent under regulations established by the Navy Department for other warrant officers. They shall take rank with other warrant officers according to dates of appointment and shall wear such uniform as may be prescribed by the Navy Department.

SEC. 16. That hereafter the term of enlistment of all enlisted men of the Navy shall be four years: *Provided*, That section fifteen hundred and seventy-three, Revised Statutes, be amended to read: "If any enlisted man or appretentice, being honorably discharged, shall re-enlist for four years within four months thereafter, he shall, on presenting his honorable discharge or on accounting in a satisfactory manner for its loss, be entitled to pay during the said four months equal to that to which he would have been entitled if he had been employed in actual service; and that any man who has received an honorable discharge from his last term of enlistment, or who has received a recommendation for reenlistment upon the expiration of his last term of service of not less than three years, who reenlists for a term of four years within four months from the date of his discharge, shall receive an increase of one dollar and thirty-six cents per month to the pay prescribed for the rating in which he serves for each consecutive reenlistment."

SEC. 17. That when an enlisted man or appointed petty officer has served as such thirty years in the United States Navy, either as an enlisted man or petty officer, or both, he shall, by making

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application to the President, be placed on the retired list hereby created, with the rank held by him at the date of retirement; and he shall thereafter receive seventy-five per centum of the pay and allowances of the rank or rating upon which he was retired: *Provided*, That if said enlisted man or appointed petty officer had active service in the Navy or in the Army or Marine Corps, either as volunteer or regular, during the civil or Spanish-American war, such war service shall be computed as double time in computing the thirty years necessary to entitle him to be retired: *And provided further*, That applicants for retirement under this section shall, unless physically disqualified for service, be at least fifty years of age.

SEC. 18. That from and after the date of the approval of this Act the active list of the line officers of the United States Marine Corps shall consist of one brigadier-general commandant, five colonels, five lieutenant-colonels, ten majors, sixty captains, sixty first lieutenants and sixty second lieutenants: *Provided*, That vacancies in all grades in the line created by this section shall be filled as far as possible by promotion by seniority from the line officers on the active list of said Corps: *And provided further*, That the commissions of officers now in the Marine Corps shall not be vacated by this Act: *And provided further*, That vacancies in the grade of brigadier-general shall be filled by selection from officers on the active list of the Marine Corps not below the grade of field officer.

SEC. 19. That the vacancies existing in said Corps after the promotions and appointments herein provided for shall be filled by the President from time to time, whenever the actual needs of the naval service require it, first, from the graduates of the Naval Academy in the manner now provided by law; or, second, from those who are serving or who have served as second lieutenants in the Marine Corps during the war with Spain; or, third, from meritorious non-commissioned officers of the Marine Corps; or, fourth, from civil life: *Provided*, That after said vacancies are once filled there shall be no further appointments from civil life.

SEC. 20. That no person except such officers or former graduates of the Naval Academy as have served in the war with

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Spain, as hereinbefore provided for, shall be appointed a commissioned officer in the Marine Corps who is under twenty or over thirty years of age; and that no person shall be appointed a commissioned officer in said corps until he shall have passed such examination as may be prescribed by the President of the United States, except graduates of the Naval Academy, as above provided. That the officers of the Marine Corps above the grade of captain, except brigadier-general, shall, before being promoted, be subject to such physical, mental and moral examination as is now, or may hereafter be, prescribed by law for other officers of the Marine Corps.

SEC. 21. That upon the passage of this Act not more than forty-five of the captains, forty-five first lieutenants and forty-five second lieutenants herein provided for shall be appointed; fifteen captains, fifteen first lieutenants and fifteen second lieutenants to be appointed subsequently to January first, nineteen hundred.

SEC. 22. That the staff of the Marine Corps shall consist of one adjutant and inspector, one quartermaster and one paymaster, each with the rank of colonel; one assistant adjutant and inspector, two assistant quartermasters and one assistant paymaster, each with the rank of major; and three assistant quartermasters with the rank of captain. That the vacancies created by this Act in the departments of the adjutant and inspector and paymaster shall be filled first by promotion according to seniority of the officers in each of these departments respectively, and then by selection from the line officers on the active list of the Marine Corps not below the grade of captain, and who shall have seen not less than ten years' service in the Marine Corps. That the vacancies created by this Act in the quartermaster's department of said corps shall be filled, first by promotion according to seniority of the officers in this department, and then by selection from the line officers on the active list of said corps not below the grade of first lieutenant; *Provided*, That all vacancies hereafter occurring in the staff of the Marine Corps shall be filled first by promotion according to seniority of the officers in their respective departments, and then by selection from officers of the line on the active list, as hereinbefore provided for.

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SEC. 23. That the enlisted force of the Marine Corps shall consist of five sergeant majors, one drum major, twenty quartermaster sergeants, seventy-two gunnery sergeants with the rank and allowance of the first sergeant, and whose pay shall be thirty-five dollars per month; sixty first sergeants; two hundred and forty sergeants; four hundred and eighty corporals; eighty drummers; eighty trumpeters; and four thousand nine hundred and sixty-two privates.

SEC. 24. That the band of the United States Marine Corps shall consist of one leader, with the pay and allowances of a first lieutenant; one second leader, whose pay shall be seventy-five dollars per month, and who shall have the allowances of a sergeant major; thirty first class musicians, whose pay shall be sixty dollars per month; and thirty second class musicians whose pay shall be fifty dollars per month and the allowances of a sergeant; such musicians of the band to have no increased pay for length of service.

SEC. 25. That the oath of allegiance now provided for the officers and men of the Army and Marine Corps shall be administered hereafter to the officers and men of the Navy.

SEC. 26. That all acts and parts of acts, so far as they conflict with the provisions of this Act, are hereby repealed.

Approved, March 3, 1899.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

The thirty-ninth meeting of this Society was held May 9 to 12, at Washington, D. C., at the Arlington Hotel, and was a conspicuous success. There was a large and enthusiastic representation of the membership and a close following of the reading and discussion of the valuable papers presented at the several sittings. We print elsewhere in this issue one of these, "Equipment of Tall Office Buildings in New York City," with special reference to the contained views regarding central power plants. This feature has a particularly important bearing on the equipment of navy yards, and also is of deep interest to naval engineers generally.

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It was fortuitous that the Society should be able to have its newly elected president, Rear Admiral George W. Melville, U. S. N., in the chair at all the sessions of this meeting and lend to the proceedings not only the interest attached to his personality but also the benefit of that tact and intuitively sound judgment in which he is excelled by no one in the engineering world. With this ideal presiding officer the proceedings were neither marked by *faux pas* nor dulled by prolixity.

Aside from the business features of the meeting, the occasion was marked by a number of most enjoyable social events, culminating in a reception given by Mr. and Mrs. George Westinghouse, which surpassed in brilliancy and decorative charm anything of like nature ever given in the Capital. Their residence, the Blaine House, was extensively enlarged by temporary additions, for the occasion, and the recollection of the surpassing beauty of the interior and the kaleidoscopic picture of the assembly will be a lasting souvenir to all who were fortunate enough to attend.

During the business sessions, at the Arlington Hotel, the following papers were read and discussed:

Wednesday Morning, May 10th, 10·30.

STANWOOD, J. B.: Standards for Direct-Connected Generating Sets.

HALE, R. S.: Boiler and Furnace Efficiencies.

EMORY, F. L.: Test of a Steam Separator.

HENNING, GUS C.: Investigations of Boiler Explosions.

Wednesday Evening, May 10th, 8·00.

EMORY, F. L.: Relation Between Initial Tension and Power Transmitted by a Belt.

NEWCOMB, C. L.: Experiments on Various Types of Fire Hydrants.

BISSELL, G. W.: Experiences with Deep-Well Pumping Rods.

NAGLE, A. F.: Pipe Flanges and their Bolts.

HENDERSON, GEORGE R.: Manufacture of Car Wheels.

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Thursday Morning, May 11th, 10·30.

BOLTON, R. P.: Equipment of Tall Office Buildings in New York City.

BULL, STORM: The Central Heating Plant of the University of Wisconsin.

DARLING, E. A.: The Power Plant of a University.

ALDEN, G. I.: The Plunger Elevator.

PRATT, C. R.: Elevators.

Friday Morning, May 12th, 10·00.

QUEREAU, C. H.: The Allen Valve for Locomotives.

FRITZ, JOHN: Rolling Mill Fly-Wheels.

GORDON, F. W.: New System of Valves for Steam Engines, Air Engines and Compressors.

CAST-STEEL PROPELLER HUBS.

The effect of the galvanic action on a propeller hub is illustrated in the accompanying cut, which is from a drawing of the developed cast-steel hub of the Revenue Steamer *McCulloch's* propeller. The ship is copper sheathed and the blades of propeller are bronze, so that the steel hub could scarcely have been expected to remain intact. The white portion of the hub represents the original surface, while the light shading is where pitting occurred to a depth of $\frac{1}{8}$ inch, and at the black parts the metal was eaten away to a depth of $1\frac{1}{4}$ inches. This effect being produced with little over two years' service.

BORNEO OIL FOR FUEL.

The oil fields of Borneo are attracting a great deal of attention from English capitalists, says the "Oil City Derrick," and the product is finding its way into general use for fuel purposes on many of the steamships of the Eastern ocean. A large number of vessels is now under construction especially designed for the use of fuel oil, and there are eight oil steamers engaged in carrying petroleum produced in Borneo to the Eastern trade. The

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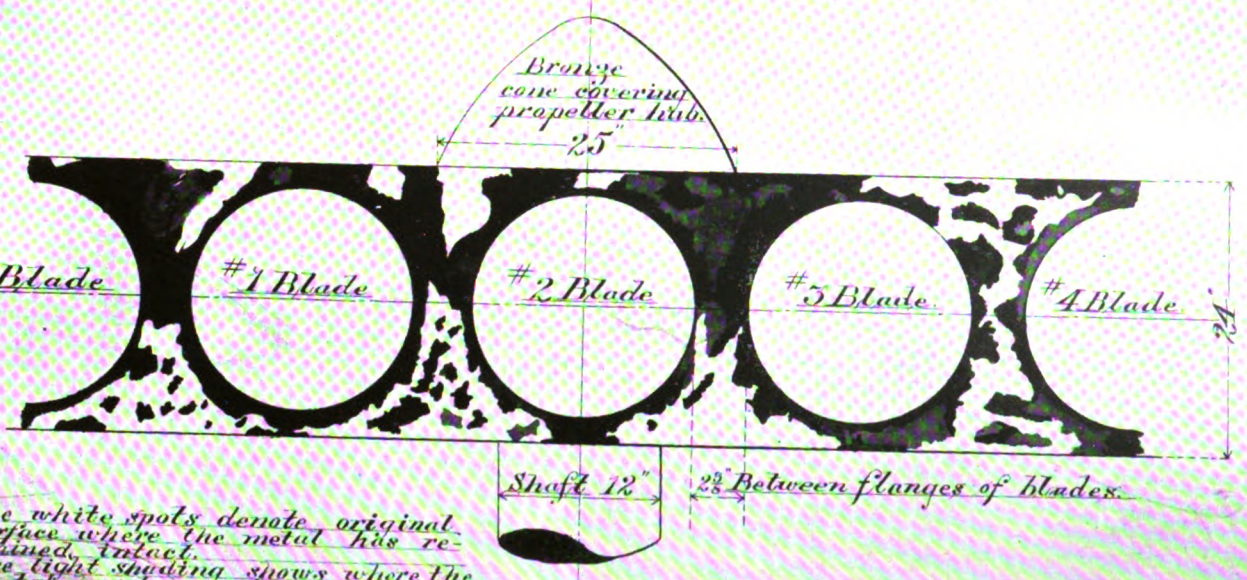

Note:

1. The white spots denote original surface where the metal has remained intact.
2. The light shading shows where the metal has been eaten away to a depth of 1/8 inch.
3. The dark shading shows where the metal has been eaten out to a depth of 1¼ inches.

U.S.R.C. McCULLOCH.
Development of propeller hub.
Showing pitted surface.

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business of transporting oil in bulk through the Suez canal is constantly increasing. In the Far East tanks have been erected at ports ranging from Yokohoma to Suez, including all the Indian ports, while cargoes of Borneo oil have also been landed at the principal ports.

Sir Marcus Sanmel, a gentleman largely interested in the development of the oil fields of Borneo, recently read a paper before the British Society of Arts, upon Borneo petroleum and its employment as fuel in steamships. As regards the development of the Borneo fields, he stated that the first steamer employed in the business of transporting oil in bulk through the Suez canal was a vessel of 4,000 tons burden of oil, while the largest of those employed now carried 6,500 tons; three steamers are in course of construction to carry 9,000 tons of oil each, or 3,000,000 gallons. There was an enormous future before this fuel, even if it only depended upon its relative cost, compared with coal; but when they came to the collateral advantages it enjoyed, the benefits of using it, as compared with coal, were simply overwhelming. As showing the immunity from danger, he said that the business having been conducted for now over seven years not a single accident of any kind had happened, either to a ship while engaged in carrying oil, or to an installation. Dealing with the relative efficiency of oil and coal, the speaker instanced the performance of the boiler of a launch used in Hong Kong. In this repeated and carefully-checked tests had shown that, while the consumption of coal was 7 pounds per minute, the consumption of oil was only 2 pounds per minute. The pressure of steam realized by 7 pounds of coal was from 96 pounds to 105 pounds, while that raised by 2 pounds of oil was sustained at 116 to 120 pounds. The speed realized in the launch under coal had never exceeded 9 knots, while under oil a speed of 10¼ knots was readily maintained. The author then dealt with the application of oil fuel to locomotives, and, in conclusion, said oil could be carried in spaces which it was impossible to utilize in any other way.

Oil carried in the bottom of a steamer, below the water line, would be impervious to shot, and by the system of service tanks, patented by Sir Fortescue Flannery, as oil was pumped out of the

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ballast tanks of a steamer water could readily be taken in to replace it. The importance of the new departure had been promptly recognized by Lloyds, who had issued regulations allowing liquid fuel having a flash point of over 200 degrees Fahrenheit to be carried in steamers' ballast tanks, and this would greatly facilitate its general use. The speaker said that the experimental stage in the burning of liquid fuel had long since been passed. No less than 7,000,000 tons per annum are consumed in Russia for liquid fuel alone. A great number of vessels, hitherto burning coal, are being altered so as to use petroleum under their boilers. The results thus far have answered the demands of vessel owners beyond the most sanguine expectations. The field for fuel oil is a large one, and most of the oil produced on the Eastern continent seems better suited for fuel than illuminating purposes.

THE PROTECTION OF IRON FROM RUST.

It is generally considered that the only thing needful for the full protection of iron is the prevention of contact with moisture, and therefore any paint which will adhere to the iron and will repel water is assumed to be a sufficient precaution. An exhaustive paper in a recent number of "Engineering," shows, however, that not infrequently the paint itself may contain or produce corrosive agents which may injure the very structure they are to protect.

One of the simplest and most generally used paints is discussed, *i. e.*, a mixture of pigment, such as red oxide of lead (red lead), or red oxide of iron, with linseed oil. Such a mixture is practically the same as a soap, similar in all respects to a soap made by mixing an alkali with an oil or fat. Now, linseed oil consists of several organic acids, and of the radicle from which glycerine is formed, and when the glycerine is eliminated by boiling with an oxide the fatty acids are in a suitable condition to become oxidized into tough elastic skins.

If these simple chemical reactions could be perfectly carried out, the production of a good protective paint would be a simple matter, but in fact it is difficult to insure the complete separation of all the glycerine. Instead, therefore, of removing all the

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glycerine, it is attempted to render it harmless by absorbing it in some material for which it has an affinity. Such absorbing materials are found in oxide of lead, oxide of iron, or various resinates, etc., which are generally used in protective paints. In some paints the free glycerine is absorbed to a large extent; for example, in red-lead paint the free glycerine is absorbed to the extent of seven-eighths, and in red oxide of iron it is absorbed to the extent of three-quarters, but in no paint is it completely absorbed, and in an effective protecting paint, therefore, some special substance must be used to complete the absorption.

The compounds known as driers or siccatifs, which are added to paint for the express purpose of quickening the drying or hardening process absorb the pure glycerine. As a matter of fact, these driers are more often than not, compounds, which also, by decomposition, eliminate glycerine, particularly so those driers which are made by boiling litharge with linseed oil. Those driers which are compounds of manganese salts, or else resinates, are the most perfect compounds for absorbing—and therefore preventing mischief arising from—the glycerine.

The danger which arises from the use of a so-called protective paint which contains free glycerine lies in the insidious manner in which it eats into the metal. The paint may appear all right, and may form a hard, smooth, and apparently impermeable coating upon the metallic surface which it is intended to protect, while at the same time it may contain in its substance, beneath the outer skin, a material which, being gradually released, is most corrosive in its action. In addition to the oxidation which the glycerine causes in the iron, it also causes the formation of blisters, and by reason of its affinity for water, it produces water-filled blisters, which gradually push up the paint and cause it to flake off. It is most essential, therefore, in the selection of a paint for the protection of structural works of iron or steel, to look for this most dangerous foe, glycerine.—"The British Press."

AN IMPROVENENT IN OPEN-HEARTH STEEL MAKING.

At the Alexandrovski Works, in Southern Russia, a modification of the Siemens ore process was introduced, in 1894, by Mr.

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Gorjainow. The ore, a hæmatite from Karnowatka, containing Fe_2O_3 87.32 per cent., SiO_2 7.70 per cent., and Al_2O_3 2.87 per cent., is mixed with 17.6 per cent. of dolomite and melted down in an open-hearth furnace, the mixture being easily fusible at about 500 degrees or 600 degrees Centigrade. Melted cast-iron is then run in, and a violent reaction takes place between the carbon of the metal and the oxygen of the ore, the effervescence being so great that the capacity of the furnace must be about four times that of an ordinary open-hearth furnace worked in the usual way. The operation is very much shortened, the charge being finished in six hours instead of twelve hours, and the consumption of scrap is considerably reduced. The furnace-bed is made of lumps of chromic iron ore, the joints being filled with a grouting of iron ore and lime. The yield in sound ingots is from 76 per cent. to 80 per cent. of the material charged, and the loss by oxidation from 12.6 per cent. to 16.5 per cent. Trials of the method have also been made at Nadjeshidinsk Works in the Ural, with an ore similar in composition to that of Karnowatka, about 40 per cent. of lime being required, as it is rather siliceous, about 24 per cent. of ore is necessary for the complete decarburizing of the pig iron. As the blast furnace was not at work, the metal was added cold to the mixture of lime and ore, which was rendered perfectly fluid in one hour and ten minutes. In this way the reaction, which begins as soon as the first portion of the ore is melted, is less violent, and a smaller furnace can be used than with direct metal from the blast furnace. The largest proportion of ore used was 30 per cent. of the weight of the pig iron, and 16.38 per cent. of dolomite, of which amount 12.28 per cent. was required for fluxing silica and 3.9 per cent. for alumina.—Stahl und Eisen, vol. xviii, 1898, p. 174.

A GAS-ENGINE DRIVE IN A MACHINE SHOP.

The following from a paper by A. R. Bellamy, read before the Manchester (England) Association of Engineers, embodies reliable information in a line with the inquiries of many of our readers. It is well known that the gas engine is much more ex-

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tensively employed in Great Britain and on the Continent than in the United States, and we can, therefore, still look for the most complete and reliable information upon this specific subject from our friends across the water. We have here, then, a straightforward account of the installation and cost of operation of a complete fuel-gas generating and gas-engine driving plant in actual operation and driving a machine shop. The paper continues:

"Our factory is of very simple design, and therefore offers no difficulties in the distribution of the power. The works are divided into two shops joined into one another, and forming a covered floor space 408 feet long by 75 feet wide. The portion we call the 'old shop' is 288 feet long by 75 feet wide, and the 'new shop' is 120 feet long by 75 feet wide. The 'old shop' has two long lines of shafting running the entire length. One line of this shafting is driven on the east side by one of our 40-brake horse-power 'Stockport' gas engines. The power is transmitted across the shop to the line of shafting on the west side by means of belts, the drive being divided half way. Here we have fixed fast and loose pulleys so that the line of shafting on the west side can be stopped when desired. From these two lines of shafting are driven all the countershafts for the tools in the main shop; also, the machines in the pattern shop, and the blower, etc., in the smithy. The total length of the main shafting is 563 feet, and it varies in size from $1\frac{3}{4}$ to $3\frac{1}{2}$ inches diameter. It is carried in 83 bearings, fixed on brackets secured to the wall. The countershafts number 87, carried in 182 bearings, and the total amount of belting is 2,500 feet, ranging from 2 to 5 inches wide. The following are the tools driven from these two lines: four fly-wheel and pulley turning lathes; five crank lathes; ten planing and shaping machines; six cylinder-boring lathes; eight drilling machines; six milling machines; five capstan lathes; thirty-five lathes, averaging 10-inch centers (20-inch swing); seven machines, various; eleven grinding and emery stones; one circular planing machine; one blower; three machines in pattern shop; making a total of 102 machines.

"The 'new shop' is driven by a second engine of 40-brake

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horse-power. This engine drives a countershaft which operates the dynamo, and also by another belt drives the line of shafting 60 feet long, 3 inches diameter, with nine bearings carried from the wall by brackets on the east side. From this shaft power is taken by belts for turning six counter shafts of a total length of 42 feet, with twelve bearings and 400 feet of belting from 2 to 5 inches wide, and the following fairly heavy tools: One planing machine to plane 12 feet long by 4 feet 9 inches wide and 4 feet high, and to cross plane 4 feet 9 inches long; one planing machine to plane 9 feet long by 4 feet six inches wide by 3 feet 6 inches high; one fly-wheel turning lathe, capable of machining fly wheels up to 9 feet diameter by 24 inches wide (this tool is fitted with back and front rests, and an independent boring and facing headstock for operating upon the boss and hole whilst the rim is being turned); one 5-feet radial drilling machine; one screwing machine; making a total of 5 machines."

The results of the horse-power tests in "old shop" were:

Power absorbed by the friction of the engine and driving belt on the loose pulley is	8.4
Main shafting, with all countershafts running, but machine belts on loose pulleys	10.5
All machines working in the ordinary daily routine	17.75
Grindstones and emery wheels	8.2
Total (indicated)	44.85

The results of the horse-power tests in "new shop" were:

Power absorbed by engine friction and driving belt on loose pulley	8.5
Countershaft for driving dynamo with the dynamo running light	3.5
Main shaft, with countershafts and all belts on loose pulleys	2.2
All machines working in the ordinary way and large fly-wheel lathe, three tools roughing out	7.8
Five-ton electric crane. Average constant horse-power, taken from a series of tests	1.8
Total (indicated)	23.8

The method adopted for getting at the power was very simple. By means of the indicator the exact horse-power was ascertained for each explosion, so that it was only necessary to count the number of impulses to obtain the requisite information. A suit-

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able counter was attached to the engine for this purpose, and diagrams were taken at intervals to make sure that there was no variation in the force of the explosion. To further check the accuracy of this method the engine was tested by the dynamometer, the number of impulses being the same as when the full shop load was on the engine, and these results corroborated the powers previously ascertained.

The test of the power for working the machines was taken over some period, and the average power was calculated from the various readings. The total horse-power that we have in the engine which drives the "old shop" is not more than forty brake or effective horse-power, and at no time during the test was this maximum power required.

It was somewhat difficult to obtain the exact amount of power absorbed by the crane, owing to its intermittent working, so we had to take observations over some time and strike an average for the constant horse-power. The maximum powers taken by the crane when loaded with six tons are as follows:

Cross traverse at 66 feet per minute, 3.0 estimated horse-power.

Longitudinal travel at 130 feet per minute, 4.6 estimated horse-power.

Hoisting at 15 feet per minute, 14 estimated horse-power.

The same dynamo that generates electric current for the crane is also used for the lighting of the shop and offices with arc and incandescent lamps. Dealing first with the power for driving the works, we have in the old shop say, 45 indicated horse-power, and in the new shop, say 21 indicated horse-power, or a total of 69 indicated horse-power. The gas consumption worked out at the rate of 67 cubic feet per indicated horse-power per hour. The costs were taken for an ordinary working week of 53 hours, with an allowance of one hour for the time the engines are running before and after shop hours. $69 \times 67 \times 54$ equals a total consumption of 249,642 cubic feet of fuel gas, say 250,000 cubic feet. Reckoning 14 pounds of fuel per 1,000 cubic feet, then the coal used equals 3,500 pounds, which at 25s. ($6.25) per ton amounts to £1 19s. 0d. ($9.75).

Tabulating the total cost for one week, we have:

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Fuel	£1	19	0	($9.75)
Labor (one man at 25s. per week)	1	5	0	($6.25)
Oil and waste for engines	0	4	0	($1.00)
Interest, depreciation and repairs at 10 per cent. on a capital outlay of £900 ($4,500)	1	16	0	($9.00)
Total	£5	4	0	($26.00)

Which is at the rate of a little under 2s. (50 cents) per hour. Reducing the cost to a single horse-power per hour, a total of 8,726 horse-power hours at a cost of £5 4s., which is at the rate of one-third of a penny (two-thirds of a cent) per indicated horse-power per hour, which covers all charges.

"*Gas Consumption.*—As our engines are worked with fuel gas, we obtained the gas consumption in this way: The gas holder was filled with gas and all connections were shut off between the producer and the gasometer. The engine was then indicated, and the number of explosions registered by the counter for each foot of fall of the gas holder. As the holder has a capacity of about 6,000 cubic feet, the result can be considered as accurate.

"*Fuel Consumption.*—This we have frequently tested, and we find that, taking an average working week of fifty-three hours, the quantity of anthracite coal required to produce 1,000 cubic feet of fuel gas is 14 pounds, which includes stand-by loss, and an allowance for generating the necessary steam for making the gas.

"*Cost of Labor.*—The gas plant is fixed in close proximity to the steam boiler. This boiler is principally used for generating steam for the steam hammers, and for heating the factory when required. One man attends to the boiler and gas plant, and we find that the latter does not take up half his time. One of the laborers looks after the gas engines, but this does not occupy his attention more than two hours per day. I have, therefore, assumed the wages of one man at 25s. ($6.25) per week to attend to the gas plant and the two gas engines. This is an ample allowance, and from my experience would be sufficient for double the power we are at present using.

"The cost of water I have neglected, as the quantity used is

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very small. The amount required for making the gas is less than 1,000 gallons per week, and there is also a little loss from evaporation in the water which circulates through the cylinder jackets. This water we obtain from a well.

"The cost of the fuel-gas per 1,000 cubic feet works out as follows:

Fuel per week, 3,500 pounds at 25s. per ton	£1	19	0	($9.75)
Labor (half man's time, at 25s. per week)	0	12	6	($3.12)
Water	0	0	0	
Interest, depreciation, repairs (10 per cent. on £400)	0	16	0	($4.00)
Total	£3	7	6	($16.87)

"As the total quantity of gas made is 250,000 cubic feet per week, the cost therefore works out to 3½d. (6½ cents) per 1,000 cubic feet.

"It is only fair to say that one man could work a plant of twice the capacity, and in so doing the cost of labor would be materially reduced. Again, an addition of £100 ($500) expenditure would double the output of gas, so that the item for interest, depreciation and repairs would be materially decreased.

"In order to make a comparison with a steam engine I again take 3,726 horse-power hours for a total consumption of 3,500 pounds of fuel. This equals 0.939 pound per indicated horse-power per hour, and includes all stand-by losses. It may be said that the cost of fuel per ton is very much higher than ordinary steam coal; but allowing it to be three times as costly, it then comes out as the equivalent of 2¾ pounds per indicated horse-power for 69 indicated horse-power, a result which will compare most favorably with the best steam engines of much greater power. We are, however, within measurable distance of making a better gas from the commonest form of slack, which will reduce the cost of fuel 75 per cent.

"Outside the question of economy there are many other advantages over steam, among which are the following: Start at a moment's notice, no time lost in getting up steam, less stand-by loss, practically no smoke, less fuel to handle and little or no ashes to remove, great economy in water, no tall chimney to build and no flues to clean.

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"Considering the matter now from the electrical engineer's standpoint, we have a total of 69 indicated horse-power driving 105 tools. The power lost in shafting which might be dispensed with, is not more than 15 horse-power, because I do not think it would be practicable to dispense with many of the counter-shafts. In any event, 105 motors ranging in size from ½ to 6 horse-power could scarcely be run to show any economy on 15 horse-power.

"It may be argued that there would be an economy in splitting up the shop into sections and driving each section by a separate motor, which would be coupled direct to the shaft. I have carefully studied this question, and have come to the conclusion that even then gas engines would be as cheap and more advantageous. In the place of each motor you could install a gas engine, and the extra friction of the engine and belt would be a little greater than the loss in the motor; besides, with each gas engine you would have an independent source of power, which is of itself very valuable. There is no method of distributing power with such little loss as by gas. In a paper read by the late Mr. Dennis Lane in June, 1893, he showed that one horse-power employed at the gas works would force through mains one mile long sufficient gas at 4 inches pressure to supply 3,000 horse-power.

"In conclusion, I should like to give you the cost of the electric light, which, as previously mentioned, is generated by the same dynamo that actuates the electric crane. Our lighting at present is a combination of gas and electric. We have nineteen arc lamps of 2,000 candle-power each, and thirty-one lamps of equal to 16 candle-power.

"The power used is 18-brake or effective horse-power. Taking 83 cubic feet of fuel gas per brake horse-power, and an average of twenty hours per week, the total consumption of gas is 29,880 cubic feet, at 3¼d. per 1,000 cubic feet, equaling, say, 8s. 2d. per week, or less than 5d. per hour for a total of 38,000 candles in arc lamps, and 496 candles in incandescent lamps."—"American Machinist."

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ELECTRICITY IN THE ITALIAN NAVY.—I.

Three years ago I contributed to "The Electrical World" some notes on the application of electricity in the Italian Navy, and, judging from the exhibits at the recent National Exposition at Turin, it is quite time to make some additions to the information therein contained. These exhibits demonstrated very clearly, I think, that the men who are engaged in working out the electrical problems of the Navy have pursued a well-defined and logical policy in the course of their improvements.

At the time of my previous article it seemed as if a system had been perfected which would be installed in the new ships without many changes. But for three or four years no large ships of war were added to the splendid fleet of armored vessels of the *Re Umberto* type, to which I referred in my article, and the progress of development in the application of electricity was brought to a standstill. The Government shipyards have proceeded very slowly with the construction of the two 10,000-ton armored vessels, *Amiraglio de Saint Bon* and *Emanuele Filiberto*, and the two armored cruisers of 6,800 tons displacement, the *Carlo Alberto* and the *Vettor Pisani*. These vessels will be completed during the current year, and the most interesting of them from the electrician's point of view will be the *Saint Bon*, which is still at the Venice Arsenal.

On the other hand, private shipyards have been very busy, and have sold to foreign powers four cruisers of similar design. Three of these fine ships are of 7,200 tons displacement, and were bought by the Argentine Republic; the other has become well known throughout the United States as a participant in the flight of the Spanish admiral from Santiago. It bears a name as dear to the conquerors as to the conquered; the name dear to us Italians also, of *Cristobal Colon*.

On these four cruisers, intended originally for the Italian navy, many new ideas and improvemeuts were worked out, and the naval authorities, in the meanwhile, were content to observe and take notes of the progress, so that presently they found themselves in a position to apply an entire new system of apparatus.

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The whole history of this revolution, accomplished in silence, was laid bare to the eyes of the initiated at Turin.

The keynote of this change lies in the multiplicity of electric motors now employed. Not only will the equipments of the new armored vessels like the *Saint Bon* and the *Filiberto* comprise a large number of motors, but the older ships also are to receive such a large addition to their motor service that the present system of distribution by special circuits and dynamos will have to be replaced by the switchboard system, enabling both circuits and dynamos to be run in parallel. The distributing boards have therefore been entirely rearranged, and the results have been very satisfactory.

A pressure of 110 volts will be used on all the new ships. The *Saint Bon* has four sets of 300 ampères capacity and arrangements for a fifth, should it be needed. It is, in fact, difficult to determine just what relations will exist between the actual average and maximum power consumption of the motors and their total capacity.

These changes have entailed others in the electrical equipment and also some permanent additions in apparatus. The aiming of guns by electrical means is now regarded as standard practice.—Guilio Martinez, in the "Electrical World," March 18, 1899.

An interesting contribution to the flash-point question is the report submitted to the Council of the Salford Sanitary Association by Mr. W. Thomson. The oil used in 15 cases of lamp explosions was examined, with the result that only in four cases was the oil of the low-flash American type, that in the other eleven being a Russian oil of higher flash point. Since very much more American than Russian oil is used in Manchester, the figures are very striking, as if one followed the simple plan of jumping at conclusions so dear to the high-flash point advocates, it would appear that the American oil was much the safer of the two. The real truth of the matter would, however, seem to be that, as unbiased experts have all along contended, the real source of most of the lamp accidents is a bad lamp. Mr. Thomson,

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indeed, reports in favor of raising the flash point to 100 degrees, but considers that if this is not done, the present standard should not be meddled with. In every serious lamp explosion investigated by Mr. Thomson, the lamp had a glass reservoir. As quite a decent lamp with a metal reservoir can be obtained for a few pence, the need for any change in the flash-point is not particularly obvious.—"Engineering," April 21, 1899.

UNITS, MEASUREMENTS AND INSTRUMENTS.—MEASURING THE SPEED OF SMALL MOTORS.

In measuring the speed of very small motors, say below 0.25 horse-power, difficulties arise because the speed counter is apt to lower the speed. To overcome this, Dr. Benischke, in a recent paper printed in the "Elek. Zeit," Feb. 16, describes a simple stroboscopic method of measuring speeds, as also the frequency of an alternating current and the slippage of non-synchronous motors. The motor to be tested has an ordinary ventilating fan connected with it; another motor is provided with a disc with radial openings through it, and is placed opposite the one to be tested, so that the fan and the disc partially overlap, enabling the former to be seen through the holes in the latter. This second motor is connected with a speed counter, and can be varied in speed; when the two speeds are nearly equal, assuming that the number of slots is equal to the number of wings to the fan, the latter will appear to rotate slowly in one or the other direction, and when the speeds are quite equal they will appear to stand still. At that moment the speed of the second motor is counted. A similar method can be applied to measuring the frequency of an alternating current when access to the generator cannot be had, and when there is no synchronous motor at hand. A bottle of water is so arranged that a small, vertical stream flows out of it in front of a small motor connected to a disc with slots in it; the bottle is mounted on a stand connected to an armature opposite an electro magnet, through which the current whose frequency is to be measured flows; this shaking of the bottle will break the stream of water into drops, whose number corresponds

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to the frequency of the current; when the number of slots passing the line of sight per second is equal to the frequency, the drops seen through them will appear to be at rest, and at that moment the speed of the motor is measured, from which and the number of slots the frequency is then calculated. In this experiment a curious result is obtained when the disc revolves somewhat more slowly, as the drops then appear to travel upward into the bottle. Instead of a broken stream of water an alternating arc lamp can be used, the light being passed from it through that rotating disc on to a screen, the speed of the motor being measured when the light on the screen ceases to surge. To measure the slippage of a non-synchronous motor the arc lamp may be used, and the disc will then appear to rotate slowly; by counting these apparent rotations in a certain time the slippage can be determined very accurately, as it is proportional to this apparent rotation. —"Electrical World," March 11, 1899.

RAPID BLUEPRINTING PROCESSES.

After much experimenting on the rapid blueprint process, I have found that the following method gives the best results: Sensitizing solution—Oxalate of iron and ammonia, 1; water (as pure as possible), 10. The iron salt dissolves in a few minutes. If a solution is prepared long in advance, it must be kept in a very dark place, in which case it can be preserved indefinitely. I would advise buying the best quality, and to make a fresh solution whenever required. The solution can be applied to the paper by means of a wide and soft brush, or the paper may be floated upon the solution in a shallow tray. The floating should last about one minute. I find brushing most convenient. The brush should be lightly loaded with liquid and be drawn evenly on the paper without passing twice at the same place. Any careful man can acquire the "hang" in five minutes.

The sensitizing and drying of the paper must, of course, be done in a dark place. The drying after brushing requires a few minutes only.

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If this paper is exposed under a tracing to the sunlight an exposure of 30 seconds only is required. On a rainy day, the window being closed, I made a very fine print in 4½ minutes by holding the printing frame close to the window.

The sensitized paper has a yellow coloration, and where the light has acted the yellow color has become bleached, and the image stands as a positive in yellow lines on white ground. Still, as the lines are very faint, one must acquire a certain amount of experience to determine accurately at sight the necessary time of exposure. After making a dozen or two small prints in different kinds of weather, the operator can generally guess at the proper time; at least that has been my experience.

Develop the print as soon as it leaves the frame. Immerse in the following solution for two or three minutes, wash in water for ten minutes, hang up to dry. The image is in white lines in a blue ground.

Developing Solution—Ferricyanide of potassium, 1; water, 30.

These proportions need not be strictly adhered to. A weak solution is all that is necessary. Red prussiate does not dissolve readily in water. It is advisable to make in advance a solution 1 to 10 in a large bottle and keep it ready for use. Dilute it as required. This solution keeps very well. Most people object to developing in a separate solution, but this process is so simple that anyone who tries it *with a will* will be satisfied.

A "one-solution process" can be operated with the following sensitizer: Oxalate of iron and ammonia, 1; water, 10. Make one solution and mix, when ready to use, with an equal part of this other: Ferricyanide of potassium, 1; water, 10. Sensitize paper as before, with a brush or by floating, and develop by simply washing in water like ordinary blueprint. The exposure required is the same as in the previous case, with the advantage that the progress of the printing can be watched. As soon as the light acts the paper turns blue. When this color is sufficiently intense, remove the print from the frame and wash. The print after washing retains the same color as before.

It is impossible to make this solution keep, and the paper

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prepared in advance keeps only one or two days in good printing condition. The lines are not very white.—Albert E. Guy, in the "American Machinist," April 6, 1899.

PROPERTIES OF NICKEL-STEELS.

The characteristics of various compounds of iron and nickel are considered. With regard to magnetic properties, nickel-steels containing besides iron and nickel only small quantities of carbon, silicon and manganese, fall into two distinct categories. The first, containing from 0 per cent. to about 25 per cent. of nickel, and which seem comprised pretty accurately between the formulas Fe and Fe_3Ni, are "irreversible," in the sense that at one and the same temperature they can exist in two essentially different states, according to the preceding cycle of temperatures. When these alloys are heated they lose their magnetism gradually between two temperatures which are comprised for all the alloys between dull red and cherry red. When they are cooled they pass again through the same temperatures without becoming magnetic, and only reacquire their first condition at a temperature lower than those between which the loss of magnetism occurs. The return to the magnetic state takes place for an alloy with 24 per cent. nickel a little below zero. The presence of chromium lowers the temperature at which the return takes place. The steel with 22 per cent. of nickel and 3 per cent. of chromium remains non-magnetic even in liquid air. Steels with more than 25 per cent. of nickel are "reversible," and possess, at each temperature, magnetic properties which to a first approximation depend only on the actual temperature. The expansion of the material has been observed by comparison with a brass scale.

The phenomenon noticed by A. Le Chatelier has been confirmed; the expansion for the same alloy is much more feeble in the magnetic state than in the non-magnetic state. The transformation is gradual as regards expansion as well as regards magnetism, and the same alloy may possess any co-efficient of expansion between two determined limits according to its degree of transformation. In one of the extreme states the expan-

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sion is a little greater than that of brass; in the other it is lower than that of ordinary steels. At ordinary temperatures the steels of the second category possess a co-efficient of expansion which varies continuously with the composition. Steels containing 35 per cent. to 36 per cent. of nickel expand ten times less than platinum. Other mechanical constants and their changes are also referred to. The alloys of the first group in passing from their non-magnetic state, where they are relatively soft and easily deformed, to the magnetic state, when they become hard and very elastic, undergo a diminution of the modulus of elasticity. The nickel-steels possess a high specific resistance, and the transformations which they undergo do not seem to affect the variations of the electric resistance; the curve of change is an ordinary one. The variation of resistance with temperature seems to be independent of the variations of volume.

For the alloys of the first sort the passage to the magnetic state takes place with increase of volume. A chemical origin is suggested for the peculiarities of behavior, and it is supposed that definite chemical compounds tend to be formed. The experiments show that the irreversible nickel-steels can possess between extended limits of temperature an indefinite number of states of equilibrium, which they keep almost without modification so long as the alloy does not cut, at low or high temperatures, two curves of transformation along which all its properties change gradually and simultaneously. They possess, besides, unstable states of equilibrium which can be broken quickly, and to which an almost instantaneous transformation puts an end. See also Phys. Soc. Abstracts, Nos. 469 and 517, 1897. J. J. S. —C. E. Guillaume, in "Journal de Physique," vol. vii, 1898; also "Comptes Rendus," vol. cxxvi, 1898.

PHYSICAL AND CHEMICAL PROPERTIES OF VOLATILE OILS IN BOILERS.

W. H. Edgar, speaking on the subject of the use of volatile oils—hydrocarbon, kerosene, and oils of that nature—in the steam boiler, says: I do not believe there are any cases in this country where we get petroleum, or other oils, in our feed-water supply;

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but the general laws of nature are such that our waters are heavily impregnated with lime and magnesia, which are the main ingredients—the scale-forming salts—which form an incrustation in the steam boiler, which incrustation is a poor conductor of heat, as compared with iron, so that we are forced to look around for something to counteract the evil effects of this incrustation, and get rid of it if possible. This has led us to put most everything into our steam boilers, and among the different reagents employed have been volatile oils. I know that they have pumped turpentine and resinous oils into boilers up in the lumber districts, because they found in districts where they were sawing hemlock and oak that the sap and washings from them have apparently kept the boilers clean, so they thought that if they put a little of the product they were working on into their boilers it would have the same effect, it all being vegetable. These volatile oils, including turpentine and oils of that nature, are all hydrocarbons, and when they have been put into steam boilers have caused a corrosion or general eating, and deleterious effects upon the boilers from their use. In the oil fields, years ago, they put in what they called an oil brick, made from petroleum, and that was not successful. In the last few years they have been in the habit of pumping into the steam boilers kerosene, etc. I know of one man in Chicago, who is at the head of some six or eight large plants, belonging to one of the largest corporations we have in the city of Chicago, who put naphtha or gasoline into his boilers for years, and would persist in saying that it did the work to perfection; but he had to stop using it, due to the leaks, etc.

There are two ways of looking at this subject of incrustation and its proper antidotal reagents. A boiler is very much like the human system. We are liable to injure it, and we are liable to put something into it where the after effects are worse than the disease; so we must take up both sides of the question. Now, I want to bring out a few points about volatile oils and kerosene. Kerosene is a light distillate hydrocarbon, and has been used very extensively throughout the country, or tried here and there, and dropped for one or another reason; and I will offer these

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suggestions and take up these points without any personal motive whatever, for I have none; but I will just simply take up the evil effects of kerosene and petroleum and their different distillates.

Kerosene pumped into the steam boiler with the object of converting the incrustation into such form that we can readily wash it out, or prevent its formation, I shall consider in the first place. Kerosene is a hydrocarbon. If we had a carbohydrate, an animal oil, we would get an oleate radical and could possibly get the oleate of lime or oleate of magnesia, which, however, would not help us out; but we could get a chemical reaction from carbohydrate, having a combining acid radical there; but in the hydrocarbons we have no possible acid radical; we have not the base; we have not the combination that will take the place of either base or an acid radical, and we get no chemical reaction whatever, and the action of the kerosene is purely mechanical, following the laws of capillary attraction. If I dip a blotter into water the water will run up the side and penetrate the blotter; if the blotter is set over a tumbler of water the water will penetrate through the substance of the blotter; and if you play a hose on a brick wall the moisture will penetrate to the other side. Now, kerosene, being a light volatile oil, will penetrate everything of a porous nature, such as lime, magnesia, etc., and will penetrate to a greater extent and more rapidly than water. The scale incrustation in the boiler will be softened, will be penetrated by this kerosene, due to the laws of capillary attraction; the scale being porous, the kerosene will work through to the iron, and when it comes in contact with hot metal the oil will run back of the sheet of scale, between the scale incrustation and the iron, and when you shut your boilers, draw your fires and let out your water, your boiler contracts, the iron contracting and expanding with the application of heat. Now, you have put a substance of different physical properties, of a different nature, between your lime and magnesia incrustation and your sheet or plate. The lime and magnesia, little particles of them, will attach themselves to the sheet, due to the general affinity that they have for hot metal; they cling very tenaciously to the iron, and when this substance comes in

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between, you have lessened that adhesive property, and the incrustation is not adhering as tenaciously, and, consequently, being a non-conductor and not expanding and contracting uniformly with the iron, it is more readily scaled off, and you get a great quantity of this broken scale from the continued use of a volatile oil, such as kerosene. The kerosene does not change the chemical composition of the scale; its action is purely mechanical.

There are other points to be considered. Kerosene volatilizes in the steam boiler; you get probably a third over with your steam; it passes off immediately and begins to come over from about 150 degrees to 300 degrees Fahrenheit. This kerosene that passes over constitutes hydrocarbon distillate, and your steam is hydrogen and oxygen, and you know the evil effects from condensation in a steam plant; you know that every year you have, in your heating system, to put in a few more nipples or an elbow here and there. When you put in a light volatile oil of a hydrocarbon nature, you intensify that action, you get a series of oxidizing hydrocarbon reagents that will intensify that general pitting and grooving 100 per cent.; that is, you will get the general eating through of the joints and connections probably a hundred times as quickly as you would otherwise. Besides that, the kerosene carries over into your cylinders. It is a part of the cylinder oil in the first place; the cylinder oils all come from petroleum, except the animal oils. The kerosene is a solvent for them. It dilutes your cylinder oil; it has a tendency to change its lubricating properties just that much, and with the hydrogen and oxygen of the water and the compound formed in the distillate you will get blackening of your piston rods and the deleterious general oxidizing effect on your rings, and if you have a metallic packing you will have hard work keeping your packing in your engine.

From these same distillates, these same products formed in your distillation, you will have the pitting and the general eating through of all the threads of the joints and connections through the entire steam system. Not only that, but the part that is left in the steam boiler and the part that goes through

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the scale and reaches the iron can not stand that high heat. It is carbonized; it is all decomposed, and in the carbonizing of the hydrocarbon oil in the presence of iron or against the iron sheet, you are going to carbonize your iron, and you will have there a blistered-appearing spot where the iron has been carbonized; it will be of a blackish, blistered appearance, and you will get that action all through the water-submerged part of the boiler. You will never get all the scale out with kerosene; you will never get more than a third; and those who are using kerosene and claim that it is working well simply look at the scale they take out, and do not look in the boiler to see what is left.

THE METRIC SYSTEM OF WEIGHTS AND MEASURES.

We are so accustomed to pride ourselves upon our *fin-de-siècle* receptiveness, and upon the readiness with which we eliminate the useless and the superstitious from the true, that it is only when we come to analyze some of our most cherished customs that we find how potent a factor is conservatism in determining our tendencies, and how all-pervading is the power of habit, even when opposed to simplicity and usefulness. A striking example of this kind is to be found in the system of weights and measures in use and in course of education in this country and in all English-speaking countries at the present time. It must be patent to everyone who calmly and dispassionately reviews our current tables of weights and measures that they are heterogeneous, ambiguous, incoherent and burdensome to the memory. It is most rarely that any man or woman in the community, excepting professed teachers of the subject, has the various tables of weights, lengths, volumes and areas so completely within the grasp of memory as to be able to reproduce them without the aid of a book. Many persons who pass for being well educated, live and die in the belief that the pound avoirdupois is the same as the pound Troy, or that the United States gallon is the same as the British gallon, or that a bushel has but one voluminal value. It is terrible to think of the waste of labor in teaching so barbarous

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a system, of the ambiguity in using it, and of the labor in performing computations with it. The advantage of the metric system of weights and measures over the ordinary heterogeneous English systems of weights and measures is as manifold and as marked as is the advantage of the dollar and cent, or decimal system of coinage, over the old English penny, shilling, crown, sovereign and guinea. No better evidence of the force of habit could be adduced than that which conserves so ridiculously complex and unwieldy a system in such extensive use.

The opponents of the metric system argue that a change to the metric system would involve nothing less than chaos and panic in mechanical construction, seeing how many thousands of tools and patterns are in use based upon the measure of the English foot or inch. This, however, is not an argument against the change, but only against a sudden change. Nothing, indeed, could be more disastrous and injurious than a sudden change to the metric system. It would be immensely costly, and, bad as the present system is, its continued use is preferable to such a penalty for rash reform. There is, however, no necessity for such extravagance. Tools do not last forever, and all things change. It would only be necessary to ordain by legislation that all Government contracts, after the lapse of a certain time, say one or two years, should be based solely upon the metric system, and the change would probably come about so smoothly and gradually under the influence of this stimulus, that in the course of ten or twenty years the present tangle would probably be forgotten.

The tangle is, perhaps, more twisted and contorted in the business of dynamo design than in any other, for the reason that the electrical and magnetic units of the C. G. S. system are very simple and easy to remember. We have no such ridiculous ratios in the C. G. S. system, as, for example, 437.5 grains in an ounce avoirdupois, or 231 cubic inches in the United States gallon. Nevertheless, in order to deal with dynamos as actually constructed in the shops, it is the almost universal practice to employ hybrid units connecting the C. G. S. measures with the English measures in a manner which, while quite clear and defi-

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nite to those who are accustomed to it, requires extra labor to learn and extra labor to compute; nor is there apparently any hope of simplification so long as the old tangle persists.—"Electrical World," April 22, 1899.

OIL SPECIFICATIONS FOR U. S. NAVY.

Specifications issued by the Bureau of Supplies and Accounts, Navy Department, April, 1899:

LINSEED OIL, BOILED.—Must be absolutely pure kettle-boiled oil of the best quality, and the film left after flowing the oil over glass and allowing it to drain in a vertical position must dry entirely free of tackiness in 60 hours at a temperature of 70° F. To be purchased and inspected by weight.

LINSEED OIL, RAW.—Must be absolutely pure, well-settled oil, of the best quality; must be perfectly clear, and not show a loss of over 2 per cent. when heated to 212° F., or show any deposit of foots after being heated to that temperature. The specific gravity must be between 0.932 and 0.937 at 60° F. To be purchased and inspected by weight.

CYLINDER OIL.—Must be a pure, mineral, hydrocarbon oil, with a flash point of at least 550° F.; burning point to be above 600° F.; to be free from tarry or suspended matter, acid, or alkali, and from mixture or adulteration with animal, vegetable, or fish oils, grease, lard, or tallow. Specific gravity to be not below 0.900 nor above 0.906 at a temperature of 60° F. To be purchased and inspected by weight.

A flash point below 550° F., or the presence of any of the above-named adulterations or mixtures, or a gravity different from that specified, will be sufficient to cause the rejection of the oil.

Test of Cylinder Oil.

1. *Flashing Point.*—Heat a small quantity of the oil in an open vessel, not less than 12° per minute, and apply the test flame every 10°, beginning at 250° F.

2. *Precipitation Test for Tarry and Suspended Matter.*—Mix 5

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cubic centimeters of oil with 95 cubic centimeters of 88° gasoline, and if there is any precipitation in ten minutes the oil must be rejected. This test is easiest made by putting 5 cubic centimeters of oil in a 100 cubic centimeter graduate, then filling to the mark with gasoline and thoroughly shaking.

3. *Volatility.*—Kept heated to 400° F., in an open vessel, it must not lose more than 5 per cent. of its weight in two hours.

4. *To Test for Acid or Alkali.*—It will be sufficient to wash a small quantity of the oil with distilled water, then drain off the water and test it with litmus paper.

LARD OIL.—Must be of the best quality and made from fresh lard. To be purchased and inspected by weight.

Oil will not be accepted which—

I. Contains admixture of any other oil.

II. Contains more acidity than the equivalent of 2 per cent. of oleic acid.

III. Shows a cold test above 42° F.

IV. Shows coloration when tested with nitrate of silver, as described below.

V. A half pint of the oil placed in an ordinary hand lamp without a chimney must burn with a clear, bright flame till 90 per cent. of the oil has been consumed; the lamp to be placed where it will not be affected by draught or air currents, and the wick not to be touched during the trial.

1. *Test of Lard Oil.*—The cold test of oil is determined as follows: A couple of ounces of oil is put in a 4-ounce sample bottle, and a thermometer placed in it. The oil is then frozen, a freezing mixture of ice and salt being used if necessary. When the oil has become hard, the bottle is removed from the freezing mixture and the frozen oil allowed to soften, being stirred and thoroughly mixed at the same time by means of the thermometer until the mass will run from one end of the bottle to the other. The reading of the thermometer, when this is the case, is regarded as the cold test of the oil.

2. The nitrate of silver test is as follows: Have ready a solution of nitrate of silver in alcohol and ether, made on the following formula:

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Nitrate of silver, ...	1 gram.
Alcohol, ...	200 grams.
Ether, ...	40 grams.

After the ingredients are mixed and dissolved allow the solution to stand in the sun or in diffused light until it has become perfectly clear; it is then ready for use, and should be kept in a dim place and tightly corked.

Into a 50-cubic centimeter test tube put 10 cubic centimeters of the oil to be tested (which should have been previously filtered through washed filtered paper) and 5 cubic centimeters of the above solution; shake thoroughly and heat in a vessel of boiling water fifteen minutes, with occasional shaking. Satisfactory oil shows no change of color under this test.

3. For the burning test, an ordinary tin hand lamp to conform to the following description will be used:

Diameter of lamp at base $3\frac{1}{8}$ inches; height of cylindrical portion $2\frac{1}{4}$ inches; height of top of burner from bottom of lamp $2\frac{7}{8}$ inches.

The burner will consist of two conical tubes placed side by side, each $1\frac{1}{2}$ inches in length, $\frac{15}{64}$ inch inside diameter at top and $\frac{11}{32}$ inch inside diameter at bottom. The wick will consist of a sufficient number of threads of ordinary cotton lamp wicking, in each tube, to make a properly fitting wick for lard oil.

LUBRICATING OIL FOR CUTTING TOOLS.—Must be of the best quality, and pass satisfactorily the following tests, to be made with instruments belonging to the Government, in the navy yard:

1. *As a Lubricant.*—On an oil-testing machine at least 50,000 foot-pounds of work must be performed per minute per troy grain of oil used. The pressure on the bearing must not be less than 250 pounds per square inch of projected area, and the temperature of the rubbing surfaces at the end of two hours must not exceed 150° F. The surfaces to be a polished steel mandrel running in standard brass bearings.

2. *Specific Gravity.*—Must not be less than 0.9000 at a temperature of 60° F. To be purchased and inspected by weight.

3. *Flashing Point.*—Must not be below 400° F.

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4. *Freedom from Gumming.*—Just sufficient oil to cover the bottom will be placed in a shallow dish; this will be heated to about 250° F., then cooled slowly. When cold, there must be no gummy residue found in the oil or on the vessel.

A common oil cup holding about two ounces will be filled with the oil; two threads of worsted will be used as a wick, and all the oil in the cup must feed through it; the wick not to be touched during the trial. This test to be made at a temperature between 70° and 90° F.

5. *Cold Test.*—The oil must not solidify at a temperature of 32° F.

6. *Freedom from Acid.*—A small quantity of oil rubbed on polished brass or copper must not turn the surface of the metal green if allowed to stand for twenty-four hours.

SPERM OIL.—Must be pure, winter-strained, bleached sperm oil, free from mixture or adulteration with animal, vegetable, or fish oil, grease, lard, or tallow. To be purchased and inspected by weight.

LUBRICATING OIL FOR EXPANDER CYLINDER OF DENSE AIR ICE MACHINE.—Must be of the best quality, free from adulteration, and pass satisfactorily the following tests, to be made with instruments belonging to the Government, in the navy yard.

1. *As a Lubricant.*—On an oil-testing machine at least 50,000 foot-pounds of work must be performed per minute per troy grain of oil used. The pressure on the bearing must not be less than 250 pounds per square inch of projected area, and the temperature of the rubbing surfaces at the end of two hours must not exceed 150° F. The surfaces to be a polished steel mandrel running in standard brass bearings.

2. *Specific Gravity.*—Must be between 0.8974 and 0.8917 at a temperature of 60° F. To be purchased and inspected by weight.

3. *Flash Point.*—Must be above 390° F.

4. *Freedom from Gumming.*—Just sufficient oil to cover the bottom will be placed in a shallow dish; this will be heated to about 250° F., then cooled slowly. When cold, there must be no gummy residue found in the oil or on the vessel.

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A common oil cup holding about two ounces will be filled with the oil; two threads of worsted will be used as a wick, and all the oil in the cup must feed through it; the wick not to be touched during the trial. This test to be made at a temperature between 70° and 90° F.

5. *Cold Test.*—The oil must remain liquid at a temperature of 7° F.

6. *Freedom from Acid.*—Must be free from all traces of acid. A small quantity of oil rubbed on polished brass or copper must not turn the surface of the metal green if allowed to stand for twenty-four hours.

WHALE OIL.—Must be best grade of bleached winter-strained oil, free from adulterations with other oils.

1. Tested with litmus paper, it must show no trace of acid.

2. It will begin to become torpid at from 35° to 42° F., and cease to flow at from 17° to 18° F.

3. Specific gravity at 60° F., from 0.9151 to 0.9174. To be purchased and inspected by weight.

4. Oil must be accompanied by a guarantee from the manufacturer that it is pure whale oil.

Inspection and Delivery of Oil.

1. Before acceptance, the oil will be inspected; samples of each lot will be taken at random, the samples well mixed together in a clean vessel, and the sample for test taken from this mixture. Should the mixture be found to contain any impurities or adulterations, the whole delivery of oil it represents will be rejected, and is to be removed by the contractor at his own expense.

2. The quantity delivered to be determined by weight—the number of pounds per gallon to be determined by the specific gravity of the oil at 60° F. multiplied by 8.33 pounds, the weight of a gallon (231 cubic inches) of distilled water at the same temperature.

3. To be delivered in strong, tight, well-made, white-oak casks, hooped with iron, each having a capacity not exceeding 50 gallons;

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4. Or, in new shipping cans, to average not less than $2\frac{1}{2}$ pounds each in weight, made of "I. C." bright tin, the black plate properly coated. The capacity of the cans to be not less than $5\frac{3}{16}$ gallons, but not more than 5 gallons of oil to each can to be paid for. The cans to be well made, with a top handle, and to have on top near one corner a $1\frac{1}{2}$-inch closed screw cap, so packed as to prevent leakage when screwed tight. Cans to be packed in wooden cases, two cans to a case, cases to be made of $\frac{7}{8}$-inch new pine throughout, dressed on outside, with tight cover, of such size as to take the cans fitting closely. The space between the cans, if any, to be filled by inserting a loose piece of wood, full width and height of can. A strip of wood of proper thickness to be inserted between the cans and cover of case, to protect the screw caps. Cans and cases to be made in the best workmanlike manner.

NOTE.—*U. S. Navy Regulation Circular No. 121* requires—

1. Deliveries of oil may be made in lots of not less than 5,000 gallons, with the exception that the final delivery may be a less quantity, but the whole quantity must be delivered within the time specified by the contract.

2. Each delivery will be considered a lot by itself; and each lot will be inspected and accepted or rejected, as it passes, or fails to pass, the test required.

3. Upon the rejection of any lot of oil delivered, no second test nor any second delivery in place of the lot rejected will be permitted, but the quantity rejected will at once be purchased in open market for the contractor's account.

GENERAL NOTE.—In making requisitions for oils, the above specifications should be referred to "*as per Official Specifications of April, 1899.*"

PATTERNS AND CASTINGS AS WITNESSES.

It is quite a common thing for apprentice patternmakers to be working in shops with which there is no foundry connected, and who therefore have to content themselves with seeing the castings after they are made, and the patterns after the molding is

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completed. To many such it may be exercising a new line of thought to consider what a chain of circumstantial evidence is presented by the castings and the patterns relative to what transpires in a foundry, and I will try, for the benefit of those so situated, to mention a few of the commonest facts that the castings and patterns testify to.

Sometimes a small pattern, when made whole, is of such shape that there is seemingly little choice as to which to consider the cope side; but by examining the casting we can tell at once which one the molder chose for that purpose, by noticing the cope or parting line around the casting. This can always be traced in outline on castings made from patterns not parted, unless the entire pattern is in the nowel, and where patterns are parted it is seen around the corresponding place in the casting. On fine work it is scarcely noticeable, but sometimes on poor work this is shown in an unsightly manner, especially when the pattern is not in halves, by the part of the casting not in the cope being distinctly larger all around the cope line, owing to excessive rapping of the nowel. The cope being a straight lift and not rapped leaves this portion of the casting true to the pattern, but the nowel is unduly enlarged.

When we see a casting made from a pattern which was in halves come with one-half distinctly overlapping the other, we may know one of two things: either that the two parts of the pattern did not fit properly, owing to loose dowel pins, or else the trouble arose from a badly fitting flask. Patternmakers always attribute it to the latter cause.

A solid pattern which sees constant service in the foundry (a pulley for example), frequently shows great wear where the cope parting is made, having the varnish worn away, and a line cut into the wood all around the center line of the spokes in this case. The constant wear of the molder's trowel against the softer pattern is the explanation.

Sometimes it is a little mystifying to the apprentice to see an old pattern completely covered on the cope side with fine dents, which look as though some one had been trying to make a poor job of stippling. This is owing to a too vigorous application of

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the vent wire in the hands of the molder, who has allowed it to strike through the mold hard enough to bruise the pattern.

Again, he will be perplexed by seeing a hole on the top side of the cope half of a pattern, which looks as though a draw iron had been stuck into it, which is not so far out of the way, after all; but it was really done for a different purpose. This hole will commonly be noticed on patterns which leave the sand very easily (the top half of a valve or pipe pattern, for example), and is done by sticking a rod into the pattern, and securing it to the cope half of the mold, so that when the cope is lifted the half pattern will be sure to rise with it, and not start to loosen before the proper time and endanger the work. After the flask is turned, of course, the rod is removed, and the pattern lifted out in the regular way.

When core boxes are returned from the foundry having holes in various places through their sides, or ends, it shows where the core maker had to vent the core, these holes being bored to admit rods for the purpose. This is something the patternmaker need not trouble himself about, as he is not expected to do it, and, besides, only certain forms and shapes of core boxes require it.

A casting readily shows whether it was pickled, rattled, or made in facing and not pickled; for, if pickled, it shows rust all over, from the acid and water of which the pickle is composed; if rattled, it is worn smooth and the corners are more or less blunt where it constantly fell among other pieces as it revolved in the tumbling barrel. If cast in a properly faced mold the sand easily peels away from it, and when cleaned the iron is left in its natural color.

A patternmaker should always bear in mind that the cleanest and best iron will be in the nowel, as the dirt and impurities will rise, and oftentimes when a perfectly clean, machined surface is required that part of the pattern must be taken for the nowel, even if it will not mold as easily that way; or else the flask must be turned over, and the mold poured the other side up. Where such precautions are necessary it is common practice to mark "cope" on that part of a pattern which must be considered as

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such when the molder would naturally consider it the opposite. Then he can use either of the two methods he chooses that I have just mentioned to get a certain part of the casting in the bottom of the mold.

I think that foundries, as a general rule, are quite willing to accommodate in such particulars, in order to have finished surfaces come with clean iron, but the patternmaker must not imagine that a foundryman who has never seen a drawing of the machine, or part, can tell by intuition where any such foresight is required, unless the pattern is marked.

Another fact that a casting bears witness to is the gating. The place where the gate connects with the mold can be readily traced, and it is interesting to note the difference in size and position on various kinds of work and in different metals. Steel castings, for example, will show gate stubs several times larger in section than would be necessary for the same piece in cast iron. Thin castings, like a common stove spider, for example, will frequently show a place 2 or 3 inches long or more, and almost a mere line in width, on the middle of the outside surface, *i. e.*, the cope side of the casting. In these the iron is poured directly through a flat sprue into the mould, and the line which we see is the place where the sprue is broken off; whereas in most small machinery castings the iron is poured into a round sprue, from which a gate is cut to the edge of the mold, and no trace of the sprue itself is visible. It is common on a casting containing a large body of iron, to see a round spot an inch and upward in diameter chipped off smooth to match the surrounding surface on the cope side. This is more apt to be the trace of a riser than of a sprue.

Many castings having quite a body of iron will show bulging places on the sides, sometimes in patches and sometimes over a large surface. This may show that the mold was not rammed hard enough, but generally it tells the tale of straining, owing to the weakness of the wooden flasks in which they were molded, especially if the flasks were old and not very strong.

If a casting is poured with cold and sluggish iron this will be

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plainly indicated by seams, called cold shuts, and these, with rounded and imperfectly filled corners, are the result.

Sometimes on a column or similar casting, having a large core, we see on the outside small, round bunches or buttons which were not on the pattern. These are done by the molder pressing the end of his trowel handle into the mold in the spot where he places a chaplet to make the core secure. What often appear to be nails showing in a casting, over or under a core, are but the remains of chaplets which did not melt perfectly in the body of iron that surrounded them. These do not appear, however, unless the casting is of such shape that further support and anchoring are required for the core that is given by the core prints.

Finally, to return to patterns, if we see a large and badly-worn hole on one that is used constantly, in the place where it was lifted from the sand, it says "draw plate" plainer than any words, and I know that many a pattern suffers from this cause to such an extent that repairs far outbalance the cost of draw plates in the beginning.

If these rambling notes should help any young patternmaker situated as I mentioned at the outset to begin to observe and examine their patterns and castings, considering them as witnesses, I think they will gather enough evidence to convict on many points, circumstantial though it be.—"American Machinist."

FRICTION OF LOCOMOTIVE SLIDE VALVES.

Experiments upon the friction of locomotive slide valves conducted upon a locomotive on the Great Southern & Western Railway were described in a paper by Mr. J. A. F. Aspinall before the Institution of Civil Engineers (England) in 1889, and the information then given has been recently supplemented by another paper by him before the same organization. The experiments were tried with valves resting against a vertical face, on an inside-cylinder engine, the steam chest being between the cylinders. The author considered it possible that the friction of slide valves, when resting upon a horizontal face, might be somewhat different from that of valves resting upon a vertical face,

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and he also desired to test the advantages to be obtained from partial balancing. The following experiments were therefore carried out upon a Lancashire & Yorkshire Railway engine at Horwich, the engine being fitted with the Joy valve gear. The recording apparatus was similar to that used in the experiments of 1889. Every care was taken to calibrate the apparatus beforehand, and to ascertain the limits of error which could be allowed for in the final experiments.

In the 1889 experiments, the indicator diagrams, which were taken to show the work done in the engine cylinder at the same moment that the fricton diagrams were taken from the dynamometer, were of the ordinary length, the motion being obtained by suitable mechanism from the piston crosshead; but in the present experiments the motion was obtained from the valve-spindle crosshead, this being considered a more accurate method of ascertaining the steam pressure at any known position of the valve. It thus became easy to obtain a simultaneous record giving a friction diagram, a steam-chest diagram and a steam-cylinder diagram, thus eliminating any error that might have been present had these diagrams been taken one after the other.

The speeds at which the diagrams were taken varied between six and eight miles an hour. Two kinds of valves were experimented with: one, an ordinary D valve made of phosphor-bronze, and the other of the Richardson type, made of cast iron, with an open back; the fixed plate against which the valve slides being also of cast iron. The annexed table gives the leading particulars of the steam pressures and other points of importance; the coefficient of friction in each case being given in the last column. Thirty-one sets of diagrams were taken with the D phosphor-bronze valve, the average coefficient of friction being 0.0878, and six diagrams were taken of the cast-iron Richardson valve, the average coefficient of friction being 0.0919. In the partially-balanced valve, the balance area was taken as being that portion which is enclosed between the strips, excluding the area of the strips themselves.

The good results obtained with the Richardson valves have caused the author to modify the views he previously expressed

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TABLE OF RESULTS.

Forward or back gear.	Notch, 1 to 4.	Push or pull.	Lubrication.	Type of valve.	Boiler pressure.	Steam-chest pressure.	Net pressure on valve.	Total force on diaphragm, corrected.	Total force moving valve.	Coefficient of friction.
			Drops per min.		*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	
F.	1	Pull.	4	Phosphor-bronze "D" valve.	156	155.0	24,149.0	1,549.5	2,099.0	0.086
"	1	"	4		152	151.5	23,562.5	1,589.0	2,126.0	0.090
"	2	"	4		158	154.0	23,405.0	1,510.5	2,056.5	0.087
"	2	"	4		157	153.0	23,037.0	1,497.0	2,039.5	0.088
"	3	"	4		144	137.0	19,513.0	1,090.0	1,575.5	0.080
"	3	"	4		154	150.0	21,619.0	1,562.5	2,094.5	0.092
"	4	"	4		146	140.0	19,455.5	1,234.0	1,730.5	0.088
"	4	"	4		158	150.0	21,077.5	1,392.0	1,924.0	0.091
B.	1	"	4		158	155.5	23,894.5	1,497.0	2,048.5	0.085
"	1	"	4		149	154.5	23,929.0	1,497.0	2,045.0	0.085
"	2	"	4		152	150.0	21,924.0	1,444.5	1,976.5	0.090
"	2	"	4		155	147.5	22,052.0	1,313.0	1,836.0	0.083
"	3	"	4		150	145.5	20,824.0	1,300.0	1,816.0	0.087
"	3	"	4		156	151.5	21,801.5	1,300.0	1,837.0	0.084
"	4	"	4		155	152.0	20,819.5	1,103.0	1,642.0	0.078
"	4	"	4		147	140.0	19,248.5	1,129.0	1,625.5	0.084
F.	1	Push.	3		160	157.5	24,461.5	3,326.0	1,767.0	0.072
"	1	"	6		158	156.5	24,291.5	2,866.0	2,311.0	0.095
"	2	"	6		159	150.0	22,907.0	1,709.0	1,177.0	0.051
"	3	"	5		160	136.0	20,568.0	2,347.5	1,865.5	0.090
"	3	"	3		159	152.0	23,032.5	1,503.0	964.0	0.041
"	4	"	3		160	148.0	20,941.5	2,620.5	2,095.5	0.100
"	4	"	3		161	148.5	20,736.0	2,532.0	2,005.0	0.096
B.	1	"	3		160	147.0	22,502.5	2,973.5	2,452.0	0.108
"	1	"	3		158	152.0	23,732.0	1,915.0	1,376.0	0.057
"	2	"	3		158	142.0	21,184.5	2,826.5	2,322.5	0.109
"	2	"	3		164	160.0	23,605.5	3,326.0	2,758.5	0.112
"	3	"	3		158	147.0	21,292.5	2,914.5	2,393.0	0.112
"	3	"	3		160	150.0	21,677.0	2,944.0	2,412.0	0.111
"	4	"	3		158	140.0	19,995.0	2,468.5	1,972.0	0.098
"	4	"	3		160	145.0	21,165.5	2,503.0	1,988.5	0.093
"	1	Pull.	4	Balanced.	144	140.0	9,467.0	420.0	916.5	0.097
"	1	"	4		142	140.5	9,514.5	393.5	892.0	0.094
"	2	"	4		140	133.0	8,633.0	288.5	760.5	0.088
"	2	"	4		158	154.5	9,976.0	393.5	941.5	0.094
"	3	"	4		143	140.0	8,704.0	354.0	850.5	0.097
"	3	"	4		152	149.0	9,238.0	236.0	765.0	0.082

NOTE.—The regulator was full open in all the experiments.

as to the advantages to be obtained from balancing. The experiments show that the friction of slide valves is somewhat greater against a horizontal than against a vertical face; the coefficient of friction found in the 1889 experiments for valves on

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a vertical face was 0.068, while in the experiments dealt with in the present paper the average coefficient was found to be for the unbalanced valve 0.0878, and for the partially-balanced valve 0.0919. There is a considerable advantage in having to overcome a force of only 854.3 pounds for the balanced, as against a force of 1,946.18 pounds for the unbalanced valves.

In connection with the 1889 experiments, opinions have been expressed that the use of the whole of the area of the back of the D valve, when estimating the coefficient of friction, was erroneous, on the ground that the only area affected by the pressure in the steam chest was an area equivalent to that of the steam ports. The argument is that if a flat plate of the same superficial area as the back of the valve were moved over another plate in the steam chest, there would be no friction; but if the lower plate had a hole, say two inches in diameter, bored through it, the force required to move the flat plate would only be that due to the pressure of the steam multiplied by the area of the hole, and as this opening became greater, so the force required to move the valve would also become greater.

In order to test this question, an experiment was made on another engine of the same class. A cast-iron plate was laid upon the ordinary valve face, and through it a two-inch hole was bored. An ordinary phosphor-bronze unbalanced D valve worked upon it, and the same dynamometer and recording arrangements were used for these experiments as for those recorded in the first part of the paper. With this arrangement it was found that a force of 2,195.9 pounds was required to move the valve with a pressure of 160 pounds per square inch in the steam chest. The plate was then taken out, and the two-inch hole was enlarged to four inches, and five one-inch holes were drilled over each of the steam ports. The dynamometer recorded exactly the same force of 2,195.9 pounds under these conditions. The intermediate plate was then removed and the valve was dropped upon the ordinary cylinder face, with the result that exactly the same force was found to be necessary to give movement to the valve. The author is of the opinion that this experiment disposes of the view that the area of the steam ports

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only should be taken into account. This is of interest, although the fact has been known for a long time in this country.—"American Engineer and Railroad Journal."

BOILER TUBE TESTS IN THE GERMAN NAVY.

The following are the specifications for tests and acceptance of water tubes for water-tube boilers and steam pipes from Siemens-Martin mild steel, as used by the German Navy.

1. *Condition of Tubes.*—The tubes must be made seamless from mild Siemens-Martin steel and must have a normal weight computed from the dimensions, based upon the specific weight of 7.850. Variations of only 10 per cent. above or below are permitted. Each tube before weighing is inspected at both ends for uniform thickness and condemned if the latter is less than 10 per cent. of the required gage at any place. Upsetting or swelling of the tube ends is only permissible after completed examination for gage. A tube shall also be condemned if its surface shows signs of treatment by files, etc., for the purpose of removing defects in the material or manufacture. Minute raised and longitudinal strips and waves in the material, if due to the method of manufacture and in excess of 10 per cent. of the normal gage, are permitted.

2. *Manner of Test.*—To ascertain the quality of the material, tensile, bending, upsetting and beading tests, one tube is chosen out of each lot of 500. This is split and flattened when hot and carefully annealed. The dimensions of the tensile test piece must correspond with the formulæ $L = 11.3\ F$, in which L represents length and F the cross section for measuring the tensile strength. If possible a length of 8 inches is to be chosen. If the dimensions will permit, tests for tension and bending after quenching, should be made with the axis and at right angles to it. The tube material must have a tensile strength of not less than 48,358 pounds per square inch with an elongation of at least 20 per cent. longitudinally with the axis of the tube, and a tensile strength of 48,358 pounds per square inch with an elongation of 18 per cent. at right angles to the axis. Tubes too small in diameter to pro-

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duce test pieces for tension and bending at right angles to the axis, must be tested by driving a mandrel into them which is 20 per cent. greater than the tube diameter; also, by upsetting a tube section of 1⅜ inches in length to one-half of this. Under these tests the material must not crack. Finally, the upsetting and bending tests should correspond in extent to the demand required, and the material show no cracks. In conjunction with the tension test a bending test after quenching will be made. The required strips of 1½ to 2 inches in width with slightly rounded edges, are heated until glowing cherry red in a dark room, and then quenched in water of 82 to 86 F. In this condition the test pieces must stand bending 280 degrees over a circle of a radius equal to the thickness of the strip without showing cracks. Only faultless sections of the tubes are to be used for test pieces. If the test pieces do not correspond with the above conditions, the 500 tubes from which they were chosen must be condemned, but the inspector shall have the right to repeat each test, and with favorable results accept the lot of tubes.

3. *Pickling of the Tubes.*—All tubes found acceptable must be pickled. The pickle consists by volume of one part of muriatic acid and nine parts of water. Each tube has to be subjected to the action of this bath twelve to fourteen hours, then laid for half an hour in milk of lime and finally washed in hot water. The surface of the tubes should be smooth after this pickling. Tubes showing holes of .02 inch and over in depth will be condemned, and also those whose surface shows many holes of small depths, with cracks or porous surface.

4. *Treatment of Tubes found Acceptable.*—Tubes found acceptable must be annealed and galvanized on the outside. All steam pipes and water tubes of large dimensions, also water tubes intended for Duerr, Niclausse and Belleville boilers, must be tested by hydrostatic pressure to 512 pounds per square inch, provided no higher pressure has been prescribed. All water tubes of smaller diameter, as well as those intended for Thornycroft, Normand, Schulz and similar small-tube boilers, after bending, must be tested cold by hydraulic pressure to 1,442 pounds per square inch without showing leaks or changes of shape.

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For fire and stay tubes of wrought iron and Siemens-Martin mild steel the specifications are as—

1. *Sources of Supply.*—The Imperial Navy Department retains the decision in the sources of supply named by the builders of the boilers.

2. *Subdivision of Order.*—Each order for fire tubes must be divided in test lots of 500 each. A remainder of 100 inclusive can be added to the last lot, but for more than 100 a separate test lot must be formed. Each order of stay tubes will be divided in test lots of 50. A remainder of 10 inclusive can be added to the last lot, but for more than 10 a separate test lot must be formed. As far as possible, tubes of like dimensions only must be included in one lot.

3. *Bending Test after Quenching.*—From each lot a sample is chosen. From this is cut, in the longitudinal direction of the tube, a strip about 8 inches long, straightened hot and machined to widths of 1½ inches, with edges slightly rounded. This strip is heated so that it will glow cherry red in a dark room and then quenched in water of 82 degrees to 86 degrees Fahrenheit. In this condition it is bent 180 degrees with a radius equal to the thickness of the strip without showing cracks after bending.

4. *Repetition of Test.*—If the test piece does not come up to the foregoing requirements then the test lot is condemned. However, if the inspector thinks that the result of the test is due to faults in the material or careless treatment of the test pieces he is allowed to repeat the test once more, and if favorable to accept the respective test lot subject to the further-on named tests. Paragraphs 2, 3 and 4 have no reference to tubes of wrought iron.

5. *Swelling of Tube Ends.*—The swelling of the gage of one end of the fire tubes, or both ends of the stay tubes, for the purpose of cutting threads, must be done by upsetting. Should the manufacture of tubes require a different manner of procedure in obtaining this greater thickness, this will have to be submitted to the Imperial Dock Yard, or for boilers built at private yards to the Imperial Navy Department. The welding on of reinforcing rings is not permitted. Should the increase

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in gage for the threads be on the exterior of the tube, then the other tube end must be swelled out until the widened wall has required thickness of the tube. The manufacture must be so arranged that the inspection for the thickness of the tubes, before they are swelled can be executed, without delaying all the other tests.

6. *Pickling.*—All tubes that have passed the previous tests must be pickled. The pickle consists by volume of one part muriatic acid and nine parts of water. Each tube must remain in this pickle from twelve to fourteen hours, after which the tubes are submerged for one-half hour in milk of lime and finally washed off in hot water.

7. *Condition of Surface.*—Tubes which show holes or cracks of depths of .02 inch or more will be condemned as those stay tubes which show holes or cracks of more than .03 inch. The same applies to tubes with surface full of small holes of minute depth or places full of cracks or pores. All tubes will be condemned that show a treatment by file or other tools for the purpose of removing slag or other surface defects.

8. *Variation of Gage.*—Each tube will be condemned if its gage, examined at both ends for uniformity, varies more than 10 per cent. from the prescribed gage. The required swelling up of fire tubes must be done only after examination for gage.

9. *Variations in Weight.*—Fire tubes and stay tubes will be weighed singly. They must have a normal weight computed from required dimensions, based upon specific weight of 7.763 for wrought iron, and 7.850 for Siemens-Martin mild steel. Variations of 10 per cent. are allowed above or below this normal weight.

10. *Hydrostatic Test.*—All tubes that have stood the above requirements will be tested cold by hydraulic pressure to twice the working pressure of the boiler for which intended. They must stand this pressure without leaking or showing lasting change of form.

11. *Preservation.*—Immediately after completed examination, the tubes will be coated with varnish, inside by means of a swab and outside by means of a rag.

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12. *Stamping.*—All tubes which have proved acceptable will be stamped on an end surface with an M surrounded by a crown. Rejected tubes will be stamped on an end surface with the letter V.

13. *Replacement of Tubes.*—The contractor will be compelled to replace free of cost all accepted tubes which prove defective when secured in the boiler upon shortest notice, usually in three weeks from the date of notification.

SUPERHEATED STEAM.

A recent editorial in the "Engineering News" upon the Design of Engines to use Superheated Steam, calls particular attention to recent progress which has been made in Europe in using this in large mill engines, and thus describes the lines upon which the work is advancing:

The secret of the great success which the European engine builders have attained is very simple. It lies in the use of vertical engines with poppet valves in connection with superheated steam. Those whose recollections extend back to the period, many years ago, when superheating was given an extensive trial, will remember that the chief difficulty found with it was the burning up of the lubricant and the cutting of valves and cylinders. It required very few experiences of this sort to give the practice of superheating a very black eye. No matter what claims might be made for theoretical economy in superheating, those who had heard of mills shut down while injuries were repaired which engines had received while superheated steam was on trial were in no mood to investigate further an innovation which promised to give rise to such troubles.

Thus it happened that superheating was abandoned, and it has remained for the studious Germans to again bring it forward and demonstrate its practicability. They have got rid of the rubbing surfaces in the cylinder by making the cylinders vertical instead of horizontal, and they have got rid of the rubbing surfaces of the valves by using poppet valves in place of slide valves.

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Both these changes, we have long held, are really valuable and inportant improvements in the design of steam engines. In a horizontal cylinder the entire weight of the piston must be carried on the bottom of the cylinder, and we have this heavy mass of metal, weighing in large engines a half ton or more, being dragged back and forth at a speed of 500 to 1,000 feet per minute on a metal pathway which can at best be very imperfectly lubricated. The natural and inevitable result is the wearing of the bottom of the cylinder until it is measureably out of round, and more or less leakage of steam past the piston occurs.

In the vertical engine, the weight of the piston is transferred directly to the crank-pin, and operates merely to slightly increase the pressure upon it on the down stroke and to relieve the pull upon it to a corresponding extent on the up stroke. The only wear upon the barrel of the cylinder is that due to the piston packing rings, and the difficulties with uneven wear and heating of the glands and packing around the piston rod are likewise overcome.

It is noticeable that the tendency of recent practice, both in this country and abroad, is toward the vertical type of engine. In electric power stations, for example, it has been rapidly gaining ascendancy over the horizontal engine for some years. From the above discussion, it seems clear that this is a change in the right direction.

Even more important than the use of the vertical engine is the adoption of the poppet valve. The piston presses with only its own weight upon the cylinder, as it sweeps back and forth ; but the slide valve is loaded with a steam pressure often equivalent to a weight of several tons.

The work done in operating a poppet valve is very much less than that required to operate a slide valve, for the load upon the poppet valve is relieved as soon as it is started from its seat, while the slide valve is loaded all the time. Further, the wear upon the slide valve begins as soon as it is put in operation, and continues with the rapidity to be expected where two hot metal surfaces rub against each other under high pressure and with

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very imperfect lubrication. The wear upon a properly designed poppet valve, on the other hand, is very slight.

It may seem strange that these manifest advantages have not brought the poppet valve into more extensive use as a competitor of the slide valve; but there are evident reasons for its neglect. In the first place, the design of a valve-operating gear which will promptly open and close a poppet valve and do it without jar or shock, is a problem by no means easy of solution. Some form of cam gear is almost essential to effect this, and American engine builders, and users as well, have never looked with much favor on cam gears, notwithstanding the high economy which has been obtained by their use.

Simplicity has always been the cry of American mechanical designers; and it certainly has saved them from the production of some such complicated extravaganzas of mechanism as have become notable in France and Germany. On the other hand, it must be said that sometimes a device is discarded as too complicated when the complication exists in the mind of the designer, who prefers some mechanism with which he is more familiar. There are poppet valve gears, for example, if we mistake not, which are much less complicated than some of the slide valve mechanisms which have been developed in the attempt to secure a slide valve which shall be relieved of steam pressure, and which shall give prompt and full port opening and release under all conditions of cut-off.

The results which are being attained by the Continental steam engine builders are already exciting the attention of American steam engine users. We know of one large electric lighting company, for example, which has for years been trying to obtain engines which would give higher fuel economy. They have had engines designed by their own engineers and built to their own drawings and specifications. They have also tried the plan of asking engine builders to submit their own plans with inducements to offer high guarantees of economy. Recently a committee of the company's managing officers was sent on a European tour, to study foreign practice in steam and electrical engineering. They returned strongly impressed with the great advances

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which have been effected there through the use of superheated steam.

A piece of additional evidence as to the interest which superheated steam is arousing in this country is furnished by the remarks of Mr. Elihu Thomson, the well known electrical engineer, at a recent meeting of the American Institute of Electrical Engineers. Mr. Thomson, it appears, has recently been turning his attention to steam engineering design, and the results of his work were stated by him as follows:

Engines as small as four horse-power can be made to develop a brake horse-power (not indicated) on about 20 pounds of water per horse-power hour. I make that statement advisedly because I have been experimenting for a year in that direction. Engines of this kind can be turned out in any machine shop without any particular difficulty, being as easy to make as any simple engine. I find, curiously enough, after doing a certain amount of work in this direction, that M. Serpollet, of Paris, has recently published a statement concerning a steam engine as applied to horseless vehicle work, and I find further that his engine is about the same as mine. This goes to show that we have been thinking pretty much in the same groove. I need make no secret as to what the engine is, because M. Serpollet has published it, although our own patents are pending. But it is so simple that it is astonishing that something of the kind has not been used or at least experimented with before. My reasoning was this: That the gas engine is an efficient engine and that I must run my steam engine on the same principle as the gas engine. In other words, I must imitate the cycle of the gas engine in steam, and then I would get high efficiency, with other advantages. If I represent an ordinary steam cylinder as an open ended cylinder, and put a piston *P* in that cylinder, well packed by rings, and either use a straight piston rod and guides in the ordinary way, or a connecting rod joined to the piston, we have the type of engine as it stands. Now instead of reversing the motion of the steam as it enters back of the piston and throwing it back to the heated surfaces in exhausting, we are careful never to throw it back, but always let it go forward. We make an ex-

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haust consisting of a number of holes uncovered by the piston at the extreme outward portion of its stroke. The piston is moving slowly when at end of stroke and there is plenty of time, if the holes are made around the piston, to discharge all the steam. In order to use superheated steam and not burn the valves or injure the engine, we use a poppet valve which is raised by proper valve mechanism in time with the rotations of the crank. Now, suppose the engine cylinder has been exhausted of steam to atmospheric pressure. Instead of letting the piston go all the way up to the end of the cylinder we can allow a clearance space similar to the clearance space in a gas engine. We can thus allow a certain compression; and the compression can nearly equal the boiler pressure, or it may fall below it. This seems to make but a slight difference. We have, therefore, adiabatic compression with a slight heating during the compression, because the steam left in the cylinder is being driven up towards hot surfaces, those that have been heated by the live steam. Then we have the poppet valve opened suddenly, and pressure rises to boiler pressure. The valve stays open but a very short time, and expansion takes place from cut-off to exhaust. The diagram resembles a gas engine diagram. What is left in the cylinder is again driven up and compressed. Now, what is the result? There is a temperature gradient from one end of the cylinder to the other. The steam always coming in hot, cools off by expansion; by the time it gets to the exhaust point it is ready to go out. It sweeps out all water condensation, and what steam is left in the cylinder is driven back on hot surfaces, dried and superheated; the poppet valve opens and makes, as it were, an explosion of steam; remains open but a small time, and expansion brings the pressure down again, and so on. The engine with four cylinders 2½ inches in diameter, 3-inch stroke, has given the result of 20½ pounds of water per horse-power hour, at 160 pounds to 200 pounds pressure.

This small engine does not condense at all; the escape is outwardly to the air. We made careful brake tests, driving a dynamo and loading the dynamo, and against the results of test is the transmission by a chain and the bearing on which the dynamo

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ran. That is, we really ought to allow about 5 per cent. more, which would bring the steam down to about 19½ pounds per brake horse-power hour. With a large engine I see no reason why it should not go down to something like 15 or 16 pounds. Surely we ought to gain something with increase of size.

Again, notice the conditions. There is no retraversing of passages, no retraversing of even the cylinder portion. The steam enters, goes forward and out, and it is running steadily forward. Thus we have a temperature gradient from one end to the other of steam cylinder. We use superheated steam, highly superheated if we please, because the engine is like the gas engine which can use flame.

DEFLECTION OF TUBES.

The accompanying table shows the results of experiments made at the Navy Yard, Norfolk, to ascertain the deflection of an ordinary boiler tube simply resting on supports at each end. The figure representing the tube shows the deflection greatly exaggerated, as, if drawn to scale, the deviation from a right line would scarcely be noticeable.

The tests were made as follows: Fair specimens of charcoal-iron tubes were used, as suitable steel tubes were not available at the time.

The surface of *A* and *B* were smooth and nearly exactly round, the diameters measured in different places along the lines 1, 2, 3 and 4 varying .01 inch.

The surfaces of *C* and *D* were not very smooth, these tubes having had a slight coat of rust, which was removed by scrubbing with brick dust and water, then washed and dried and rubbed bright with emery cloth, leaving them slightly rust-spotted in places. The diameters measured as on *A* and *B* vary .04 inch.

Each tube was placed over the table of the large planer, the ends resting one-half inch on parallel blocks; the planer table having been carefully cleaned and made smooth along the line over which the measurements were made.

The space between the parallel blocks was divided, as shown on the tracing, Fig. 1, and the corresponding measurements for

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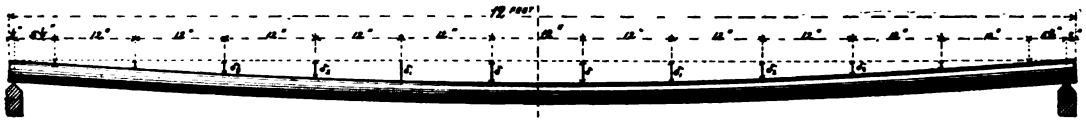
DEFLECTION OF TUBES.



A.—Seamless Drawn Brass Tube. 12 ft. long.

— 2.5 ins. outs. diam. — 2.356 ins. inside diam. — .072 ins. thick. — 14.5 lbs. total. — 1.209 lbs. p. ft. —

	δ_5	δ_4	δ_3	δ_2	δ_1	δ	δ	δ_1	δ_2	δ_3	δ_4	δ_5
Deflection.	.0290"	.0777	.1300	.1730	.2065	.2185	.2160	.2042	.1720	.1357	.0802	.0315
Mean of the 2 ends.	—	—	—	—	—	—	.2175"	.20535	.1725	.1328	.0789	.0352

B.—Seamless Drawn Brass Tube. 12 ft. long.

— 3. ins. Outs. diam. — 2.834 ins. inside diam. — .083 ins. thick. — 25.76 lbs. total. — 3.146 lbs. p. ft. —

Deflection.	.0165"	.0355	.0520	.0542	.0867	.0935	.0938	.0882	.0760	.0540	.0362	.0122
Mean of the 2 ends.	—	—	—	—	—	—	.09365"	.08745	.0651	.0531	.0358	.0148

C.—Charcoal Iron Boiler Tube. 12 ft. long.

— 2.5 ins. Outs. diam. — 2.204 ins. inside diam. — .148 ins. thick. — 33.75 lbs. total. — 2.812 lbs. p. ft. —

Deflection.	.004"	.03625	.0385	.05125	.0595	.06675	.07075	.065	.05925	.04225	.029	.0125
Mean of the 2 ends.	—	—	—	—	—	—	.06875	.0622	.05525	.0388	.03262	.0082

D.—Charcoal Iron Boiler Tube. 12 ft. long.

— 3. ins. Outs. diam. — 2.704 ins. inside diam. — .148 ins. thick. — 41.75 lbs. total. — 3.478 lbs. p. ft. —

Deflection.	.00125"	.012	.02325	.0345	.04825	.04375	.04825	.04921	.0415	.03375	.02525	.0145
Mean of the 2 ends.	—	—	—	—	—	—	.04600"	.04873	.0380	.0285	.018625	.01787

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each tube were made over the same spots. A steel plate, 2 by 1 by ½ inch was planed and finished with the broad surfaces parallel, and this was used to place on the table over each division to eliminate any slight irregularity in the surface of the table. The distance between the top of this plate and the under side of each tube was measured with an inside micrometer caliber capable of measuring accurately to .0005 inch. Each tube was measured at intervals along its length, as shown on tracing, then turned a half revolution and measured again; then turned a quarter revolution and then a half, so that each was measured on four (4) sides.

The measurements obtained are shown in the tables, the whole number of inches (2), being the same for each, are left off, the decimal parts only being given.

THE LOSS OF HEAT FROM LOCOMOTIVE BOILERS.

The most elaborate series of tests ever undertaken to determine the loss of heat from locomotive boilers were made last summer by the Chicago & Northwestern Ry. Co., in co-operation with several manufacturers of boiler coverings. A complete report of these tests was given in a paper read at the January meeting of the Western Ry. Club by Mr. Robert Quayle. The tests were made under the general direction of Messrs. W. H. Marshall and F. M. Whyte and Prof. W. F. M. Goss. The complete paper and discussion is much too long to give space to here; but we have prepared the following abstract containing the substance of the paper:

Plan of the Tests.—In carrying out the tests two locomotives were employed; one, to be hereafter referred to as the "experimental locomotive," was subject to the varying conditions of the tests; the other was at all times under normal conditions, serving to give motion to the experimental locomotive, and as a source of supply from which steam could be drawn for use in maintaining the experimental boiler at the desired temperature. The experimental locomotive was coupled ahead of the normal engine, and, consequently, was first when running, to enter the

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undisturbed air. The action of the air currents upon it, therefore, was in every way similar to those affecting an engine doing ordinary work at the head of a train.

The boiler of the experimental locomotive was kept under a steam pressure of 150 pounds by a supply of steam drawn from the boiler of the normal engine in the rear. There was no fire in the experimental boiler. It was at all times practically void of water. Precautions were taken which justified the assumption that all water of condensation collecting in the experimental boiler was the result of loss of heat from its exterior surface. This water of condensation was collected and weighed, thus serving as a means from which to calculate the amount of heat lost.

The Experimental Boiler.—The Chicago & Northwestern locomotive, No. 626, the boiler of which served in the experiments, is of the 8-wheel type, weighing about 90,000 pounds. The principal dimensions of the boiler are as follows:

Diameter, inches	52.0
Heating surface, square feet	1,391.0
Total area, external surface, not including surface of smoke-box	358.0
Area of surface lagged, square feet	219.0
Area of steam-heated exposed surface not lagged	139.0
Ratio of surface covered to total surface	.61

It should be noted that the values given above are based upon projected areas of the plain boiler. No account has been made of the edges of plates at joints, or of surface due to the projection of rivet heads, or to the surface of various attached projections, such as running-board brackets and frame fastenings. While all such projections above the general surface of the boiler are active agents in conducting heat from the interior, the present study does not require them to be taken into account. The extent of area covered for this boiler is entirely normal for the class of locomotives to which No. 626 belongs, which gives added interest to the fact that but 61 per cent. of the exposed surface of the boiler was covered.

The tests made were of two sorts: First, with the experimental engine at rest, which test will be hereafter referred to as the "standing test;" and the second, with the experimental boiler in motion at a rate of speed, approximately, 28.3 miles per hour,

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to be hereafter referred to as the "running test." Both standing and running tests were made with the experimental boiler bare, and also when protected by six different coverings. Tests of two of these were repeated, making altogether nine standing tests and nine running tests to be reported. These are designated as follows: A, B, C, D_1, D_2, E, F_1, F_2 and G. A represents the test of the bare boiler. D_1 and D_2 are different tests of the same covering, and, similarly, F_1 and F_2 are tests of a single covering.

Results.—The observed and calculated results are summarized as follows:

Pounds of steam condensation per minute.

	A*	B	C	D_1	D_2	E	F_1	F_2	G
Standing test	6.78	2.63	3.42	2.91	2.80	3.52	3.04	3.22	3.03
Running test	14.2	5.68	5.47	5.03	5.34	5.21	5.29	5.30	5.70

*Bare boiler.

The values, as given, have been reduced to a common basis with reference to steam pressure, atmospheric temperature, and running speed, and, so far as these factors are concerned, are comparable. They have not been corrected for variations in thickness of covering, which in all cases was slight or for variations in the velocity and direction of the wind.

Efficiency of Coverings.—The percentage of the heat transmitted from the bare boiler, which is saved by any covering, may be obtained by subtracting the amount of condensation for the covering in question from the condensation for the bare boiler, and by dividing one hundred times this difference by the condensation for the bare boiler. The result expresses the efficiency of the covering. Values thus obtained are as follows:

Efficiency of coverings as disclosed by running tests:

	Per cent.
B,	60.2
C,	61.7
D_1,	64.8
D_2,	62.2
E,	63.5
F_1,	62.9
F_2,	62.8
G,	60.1

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The results appearing in this table are corrected for variations in steam pressure, atmospheric temperature and speed, but not for variations in weather and wind conditions or for variations in thickness of covering. The average efficiency disclosed by the eight tests is 62.3 per cent.

The conclusion, stated in very general terms, is that any of the coverings tested can be relied upon to save from 60 to 64 per cent. of all the heat which would radiate from the boiler were it not covered at all.

One Reason for Similarity of Results.—The fact that the results obtained from the several coverings are so nearly alike can hardly fail to occasion surprise. Had thin layers of the material tested been subjected to carefully planned laboratory tests, the results would doubtless have differed more widely, but it must be expected that the value of such difference will diminish as the specimens experimented upon are increased in thickness. A material which is rather an indifferent non-conductor will serve to prevent the passage of heat if applied in sufficient thickness. While, therefore, the coverings tested were of normal thickness, it would seem that this thickness is sufficient to reduce to a negligible amount the effect of the superior non-conducting properties which the material of one covering may have possessed over others.

Efficiency of Covering and Heat Loss from Different Portions of the Boiler.—The results show that the covering of 61 per cent. of the exterior surface of the experimental boiler saves 62.3 per cent. of all the heat radiated from the same boiler under similar circumstances when bare. It does not, however, follow from this statement that if 100 per cent. of the exposed surface of the boiler were covered, 102 per cent. of the heat lost from the bare boiler would be saved. Such a conclusion must obviously be absurd, though a hasty consideration of the facts presented might seem to justify it. The fact as first stated, however, proves that there is a vast difference in the character of the exposure to which different portions of the boiler are subjected. While only 61 per cent. of the surface of the boiler was covered, the protection was evidently applied where it was most needed. The per-

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centage of the total exposure guarded against was greater than the percentage of surface covered. For this reason, increasing the covered area by 10 per cent. cannot be depended upon as a means of reducing radiation losses by a like amount. It will reduce loss, but the amount of the reduction may be very much less than 10 per cent. It is for this reason, also, that all comparisons in this report have been based upon the boiler as a whole. The radiation is stated in terms of pounds of steam condensed per minute for the boiler experimented upon, rather than as pounds per minute per square foot of exposed surface. The latter unit would be a more general unit, but its use in interpreting the data under consideration would be misleading.

Radiation and Its Power Equivalent.—Assuming that a locomotive will develop a horse-power by a consumption of 26 pounds of steam per hour, and assuming that the steam thus consumed must be generated from water at 80 degrees Fahrenheit, the radiation losses already given may be expressed in terms of power losses of equal value. The practical effect of these assumptions is to define a horse-power as equal to the condensation under the conditions of the tests of 34 pounds of steam per hour, the steam having a pressure of 150 pounds and the water the temperature due to the pressure. Upon this basis the following results are obtained. They apply only to the boiler tests.

Horse-power lost by radiation:

Bare boiler.	
Locomotive at rest, under conditions of test	12.
Locomotive running 28.3 miles per hour and otherwise under conditions of test	25.
Boiler lagged as in test:	
Locomotive at rest, under conditions of test	4.5
Locomotive running 28.3 miles per hour and otherwise under conditions of test	9.

A locomotive similar with that tested may be expected to deliver a maximum of 600 horse-power. It is evident that if the uncovered boiler were under conditions of speed, etc., which are now uncommon in service, that at least 10 per cent. of the total power of the machine would be lost in radiation from its

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exterior surface. This, then, discloses the extent to which locomotive performance may be affected by radiation. A perfect covering enveloping the entire external surface of the boiler would prevent the entire loss. Actual coverings, such as those tested, extending over a portion of the surface, prevent approximately 62.3 per cent. of the loss. It seems to be a fact, therefore, that a boiler protected in accord with good practice loses power when standing in warm weather, at the rate of 4½ horse-power, which amount will increase if the pressure of steam is increased, or the temperature of the atmosphere is reduced, or the engine is put in motion.

Cost of radiation from the boiler experimented upon may be stated as follows:

BARE BOILER.

Pounds of coal per hour equivalent to radiation losses, assuming evaporation from and at 212 degrees Fahrenheit, of 6 pounds of water per pound of coal—	
When standing	60
When running 28.3 miles per hour	126
Tons of coal per month, assuming boiler to be under steam standing 200 hours and running 28.3 miles per hour during 300 hours per month	25
Cost of radiation per year for the boiler tested, assuming the conditions of the preceding paragraph and assuming the price of coal $2 per ton	$600

As locomotives are never run entirely bare, the estimated annual loss by radiation, of $600 per engine, is higher than would be likely to occur on any engine in service. It is, however, a statement of the total loss which may occur, and as such will be useful in estimating the value of savings which may be effected by the application of coverings.

It has been shown that the several coverings tested have an efficiency which is not far from 62.3 per cent. The annual saving, therefore, which would be effected by the application of any of the coverings would be

$$\$600 \times .623 = \$383.80,$$

the remaining $226.20 still going to waste through radiation. The results show that anything which will increase the efficiency of the covering on the engine tested by 1 per cent. will result in a saving of $6 per annum. A 2 per cent. increase of efficiency will save $12, a 3 per cent. increase 18, and so on. This holds

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good for the particular engine tested and for the conditions under which the engine was tested.

The fact should be emphasized that the results thus far given are those derived from the actual experiments. These involved a boiler of moderate size, carrying steam pressure which is now regarded as low, and were conducted in the month of August. It should be noted, also, that the running tests involved a speed of less than 30 miles per hour. It is evident that other conditions, quite common to actual service, would operate to greatly increase the radiation losses described. The effect of changes in some of these conditions will next be considered.

The effect of changes in speed on radiation has long been an open question. It has been argued that a boiler perfectly covered would be, to a very great extent, unaffected by surrounding air currents, and hence that its radiation losses would not be materially greater when the locomotive is at speed than when standing. But those who appreciate the intensity of the cooling currents which circulate about a locomotive when at speed have been slow to accept such a view, and the tests under consideration confirm their position. They give a measure of the radiation losses, both when the locomotive is at rest and when moving at a uniform speed of 28.3 miles an hour. While these points are not sufficient to establish with accuracy the complete relationship of radiation and speed, an estimate of real value may be based upon them. Such an estimate shows that the bare boiler, when at rest, radiates sufficient heat to condense 6.78 pounds of steam at 150 pounds pressure per minute, which amount is increased to 28 pounds when the same boiler is driven at a speed of 80 miles an hour. Similar values for the covered boiler are 3.0 pounds and 10.6 pounds respectively.

Changes in Atmospheric Temperature.—The results recorded were obtained in midsummer and all have been corrected for an atmospheric temperature of 80 degrees Fahrenheit. For each 10 degrees reduction in atmospheric temperature below 80 degrees the radiation may be expected to increase 3.5 per cent. For a zero temperature the radiation losses recorded in this report should be increased by about 28 per cent. For example,

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if, when the atmospheric temperature is 80 degrees the conditions are such as result in the condensation of 5 pounds of steam per minute; when the atmospheric temperature is zero the condensation will be

$$5 + 5\,(.035 \times 80) = 5 + 1.4 = 6.4$$

From this it appears that very low temperatures are attended by radiation losses of considerable magnitude.

Changes in Steam Pressure.—The experiments were conducted under a boiler pressure of 150 pounds by gage. With an increase of pressure the boiler temperature will become higher, and the radiation losses will, as a consequence, be augmented. Changes arising from this source, however, are not great. For each 10-pound increase of pressure above the limit of 150 pounds the radiation may be expected to increase by about 1.6 per cent., but this will not apply for pressures much above 200 pounds. A pressure of 200 pounds will involve losses by radiation which are 8 per cent. greater than those making up the record of this report.

Possible Losses from the Boiler Experimented upon.—Applying the results expressed in the preceding paragraphs, it can be shown that with the boiler bare and the locomotive running at 80 miles an hour, under a steam pressure of 200 pounds, with the atmospheric temperature at zero, the loss by radiation would be the equivalent of 67 horse-power, while a covered boiler running under the same conditions of speed, pressure and atmospheric temperature, would still be subject to a loss of 25 horse-power. As a locomotive similar to that tested may be expected to deliver a maximum of 600 horse-power, it is evident that under the extreme conditions just assumed, which are not at all uncommon to service, at least 10 per cent. of the total power of the engine would be lost in radiation. This is for an uncovered boiler. An application of any of the coverings tested would reduce the loss to about 4 per cent.

Size of Boiler.—In reviewing the facts presented in the preceding paragraphs, it will be well to keep in mind the fact that the boiler tested was one of moderate size. Many boilers are

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now running which present an exposed area which is at least 50 per cent. greater than that presented by the boiler under test, and it should be evident that the losses from such large boilers will be greater than those disclosed by the tests under consideration. For boilers of the same general type the loss will probably be proportional to the exposed surface.

Conclusions.—In view of the very strong air currents which circulate about the boiler of a locomotive at speed, it is not surprising that the losses by radiation are large. While their value is dependent upon conditions which may vary widely, they always go on whenever the boiler is under steam. In this respect radiation losses are unlike those which occur within the engines of the locomotive, since, to a considerable extent, these latter cease to operate whenever the throttle is closed.

All of the experimental results and the conclusions based upon them were obtained from an engine of moderate size, carrying a pressure which, in the light of modern practice, must be considered low, and under conditions of summer atmosphere. The running speed, also, was not high. These conditions cannot be considered as in any way calculated to disclose large radiation losses, and yet the results are such as will merit the earnest attention of all who are interested in improving locomotive performance. In this connection it will be well to again emphasize the fact that the losses which have been measured and which are defined in this report do not include radiation from saddles and cylinders, or from any portion of the locomotive excepting the boiler itself.

It may be assumed that the boiler, as covered in each of the several tests involving covering, was as well protected against radiation as is the average boiler of American locomotives, notwithstanding the fact that when thus covered there is still a loss of heat, which in money value annually represents many times the cost of the best covering which the market to-day affords. Improvement is to be found not only in improving the character of the covering itself, but chiefly, probably, in extending the covered area of the boiler and projections attached thereto.—"Engineering News."

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MISCELLANEOUS.

THE LATEST AND LARGEST HYDRAULIC PRESS.—A correspondent of the "American Machinist" says: I notice in your issue of March 16, 1899, an article headed "The Latest and Largest Hydraulic Press." While it may be the latest, it is by no means the largest, as you will note from the following comparison, based on figures which represent the dimensions, etc., of a hydraulic press which we have at the works of the Bethlehem Iron Co., and which has now been in operation for several years:

	B. I. Co.	Parkhead.
Maximum capacity	14,000 tons.	12,000 tons.
Diameter of plungers	(2) 50½ in.	(1) 72 in.
Total area plungers	4,006 sq. in.	4,071 sq. in.
Pressure per square inch	7,000 lbs.	5,900 lbs.
Width frame inside the columns	14 ft. 6 in.	15 ft.
Working height under crosshead	17 ft. 1¼ in.	13 ft.
Power supplied by	(3 sets cylinders) 54 x 90 in.	(4 sets cylinders) 21 in., 43 x 18 ft. stroke*
Balance cylinders (H. P.)	(2) 13 in.	(2) 15 in.
Balance accumulative pressure	2,000 lbs. sq. in.	1,300 lbs. sq. in.

*This is probably a mistake. 18 feet is a long stroke.

A MARINE BRAKE.—The following extract from a recent report of H. Albert Johnson, United States Consul at Venice, appears in "The Marine Review," Cleveland, Ohio, March 16: "The agent of the Austrian Lloyd Steam Navigation Company, in Venice, has brought to my notice an interesting series of experiments recently conducted at Fiume by the director of the Lloyd shipyards. The experiments tested the efficiency of an invention by a Hungarian engineer, Mr. Svetkovich, for stopping vessels under full steam. The Austrian Lloyd placed its towboat *Clotilde* at the disposal of the inventor, and three trials were made to test the invention under different conditions. This marine brake is a sort of parachute of fine spring-steel plates which, when out of use, fit into one another and hang above water. For the first trial, the apparatus was attached to the stern of the *Clotilde*, and the steamer put on full steam. When maximum speed was attained—in Austrian reckoning, 9 miles per hour—the retaining hook was released, and the parachute plunged

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into the water. With a scarcely perceptible shock the vessel came to a standstill in thirty feet. It was found, however, that the rods and guys supporting the brake were badly strained. If they had not yielded the shock would have been much more severe. The fact that the supports did yield did not argue seriously against the efficiency of the brake, but was attributed to the provisional character of the arrangements. The second trial was designed to show how far the vessel would proceed when her engines were stopped at full speed, no brake being used. The distance was found to be 300 yards. The third trial measured the forward movement when the engines were reversed from full speed astern. This time the *Clotilde* stopped in sixty yards. While the second and third trials were in progress, the marine brake was refitted with more powerful supports, and a fresh experiment was made. This time the vessel stopped almost instantly. These results, while hardly to be considered valid for the powerful ocean liners, with which the necessity for a quick stop is occasionally so crucial, indicate that an important principle has been introduced among marine safeguards. The Austrian Lloyd Company is awaiting with interest the results of an improvement which Mr. Svetkovich wishes to add to his device, and seriously contemplates equipping its great fleet with the useful apparatus."—"Literary Digest."

A System of Printing Telegraphy, known as "Professor Rowland's Multiplex," was recently tested between Philadelphia and Jersey City with highly satisfactory results. On this system a message is sent and received in legible and easily read type, transmitted from keyboards similar to those of a typewriter, the characters including simply the ordinary alphabet and numerals. The device on trial was made at the Johns Hopkins University, in order to demonstrate what merits it possessed and also its weakness, if any, and it is arranged for eight messages, four in each direction, and duplexed in the usual way. The messages are printed on either a tape or a page, and a speed of sixty words a minute has been obtained in some of the experiments, but the limit of speed or the number of messages was not reached.

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There is no other multiplex printing system sending from a keyboard and received on a page, and this one is only a part of that invented by Professor Rowland. The whole invention contemplates a relay method, by which any amount of territory may be covered, and comprises a system by which eight people in one city can be in communication with eight others in another place over one wire and with absolute secrecy. Among the advantages claimed for the multiplex system is that of less liability of error, since there is only one person engaged, and he the sender; while, by the Morse system, there is an opportunity for mistakes at each end of the line.—"Engineering," April 21, 1899.

Gas Engines for Operating Electric Plants.—Mr. Oliver F. Allen gives in "Progressive Age" the result of inquiries sent to thirty-five users of gas engines for operating electrical plants. Of twenty-four replies received, the writers of fifteen are entirely satisfied, and have had no trouble, four have had some trouble with igniters, one has had trouble in starting with a cold cylinder, one engine requires too much attention, one is not able to give information on account of engines not running yet, one is doubtful and one is condemnatory. Seventeen of the engines reported are from 125 to 30 horse-power in size, and the owners of the larger engines particularly express much satisfaction from their use. The gas consumption reported varied from 13.6 to 30 cubic feet per B.H.P., on the basis of 650 B.T.U. gas. Various makers communicated with guaranteed consumptions ranging from 15 to 20 cubic feet per B.H.P.

A Velocity of 3,000 Feet Per Second was recently recorded in the late tests, at Indian Head, of the new 45-caliber 6-inch U. S. naval gun. This is claimed to be the best record made by a gun of this class. The Krupp 15-centimeter (5.87-inch) and the 16-centimeter (6.3-inch) use projectiles weighing 88.2 and 110.2 pounds respectively; but the highest muzzle velocity recorded for these is 2,635 foot seconds. These guns are 50 calibers long. The Krupp 21-centimeters (8.24-inches) uses a projectile weighing 238.1 pounds, and is credited with a muzzle

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velocity of 2,822 foot seconds; and the same velocity has been obtained with a Krupp 24-centimeter (9.45-inch) gun, with a projectile weighing 352.7 pounds. The nearest French gun in type is the Schneider-Canet quick-fire, 5.91-inches caliber, using a projectile weighing 88.2 pounds. With lengths of 45, 50 and 60 calibers this gun shows velocities of 2,625, 2,756 and 2,953 foot seconds respectively. The 60-caliber length is an experiment, and the 45-caliber is the one to be compared with the American gun. The 6-inch Elswick guns of 50-calibers claim a velocity of 2,940 foot seconds, but the British naval authorities say that the velocity is not desirable, owing to the great wear on the gun. The American full tests are not made public; but it is claimed that the results were due to a new smokeless powder recently adopted by this Government.—"Engineering News."

ILLUMINATING SHELLS for lighting up large areas of ocean in life-saving work, or to obtain the range of the vessels of an enemy, are proposed by the American Illuminating Shell Co., of Baltimore, Md. The shell used is a hollow cylinder made of steel tubing, and charged with calcium carbide, which, coming into contact with water, generates acetylene gas. The end of the shell remains above water, and at this end are burners lighted by an electric device contained in the shell. It is claimed that the light produced is of 1,000 candle power and cannot be extinguished by water. The shell is to be shot from a gun to a distance of two miles, and floats with one-quarter of its length above water. —"Engineering News."

PROPELLER BLADES AND RUDDERS.—Steel propeller blades are being made by the Penn Steel Casting and Machine Company, Chester, Pennsylvania, for the ocean steamers *St. Louis* and *St. Paul*, of the International Navigation Company, each weighing five tons. These blades, bolted on the hub in their proper place, would make a wheel twenty feet in diameter. The company has also made solid cast-steel rudders, cast in one piece, weighing about eleven tons, for the steamers *Waesland* and *Kensington*, and it has an order in hand for another solid rudder for the

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steamer *Southwark*, and also two for new steamships now being built on the Clyde for the same navigation company. The latter two rudders will weigh each fifteen tons.—"Engineering," March 24, 1899.

THE EQUIVALENT OF A WATT HOUR IN MECHANICAL UNITS.—One way of defining a watt hour is to say that the energy represented by it is equal to that expended in raising a pound to a height of 2,654 feet, or two watt hours correspond almost exactly to raising a pound to a height of one mile. Applying this to primary batteries gives results which at first sight are rather surprising, as they show how much energy is stored in them. A certain dry battery, for instance, weighing 6.38 pounds, yielded 130 watt hours, which, if applied to raising the battery itself, would lift it to a height of over ten miles. In one hour the energy translated in an ordinary 16-candle-power lamp weighing about an ounce would raise that lamp to a height of 400 miles at a velocity of nearly seven miles per minute.—"Electrical World."

BOILING POINTS OF LIQUEFIED GASES AT ORDINARY ATMOSPHERIC PRESSURE.—The following table may prove itself as a record:

	Deg. Cent.
Sulphur dioxide,	— 10
Chlorine,	— 33
Ammonia,	— 38
Sulphuretted hydrogen,	— 62
Carbon dioxide,	— 78
Nitrous oxide,	— 88
Ethylene,	—102
Nitric oxide,	—153
Marsh gas,	—164
Oxygen,	—183
Argon,	—187
Carbon monoxide,	—190
Air,	—192
Nitrogen,	—195
Hydrogen,	—238

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SEARCHLIGHTS IN THE ICE—It is stated from Cleveland that searchlights have proved useful this winter in the heavy ice on the lakes. When they were first placed upon the Detroit and Cleveland steamers they were regarded more as an ornament and advertising medium than anything else, but time and again have the searchlights proved their great value as an actual aid to navigation. With the powerful stream of light from the pilot house the helmsman is enabled to pick his way through the ice fiels and much time is saved.—"Electrical World."

THREE INDEPENDENT SETS of dynamos and engines are required to light H. M. S. *Irresistible* (the first-class battleship, christened at Chatham Dockyard on December 15th, by H. R. H. Princess Christian), and to work the electric-motor fans and the six powerful search lights with which the ship is fitted. Every compartment of the vessel, except in the double bottoms, will be lighted by incandescent lamps, and Colomb's lights are fitted for use when the dynamos are not running. The ventilation will be secured by means of the motor fans. There is also to be a complete insulation of electric bells and voice pipes, together with a system of loud-speaking telephones in various parts of the vessel. There is a steam capstan forward, but the after capstan is to be worked by two electric motors, supplied by Messrs. Clarke, Chapman and Co., of Gateshead-on-Tyne.—"Engineers' Gazette," January, 1899.

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SHIPS.

UNITED STATES.

New Vessels.—The Naval Appropriation Bill for the fiscal year ending June 30, 1900, made the following provision for new ships under Increase of the Navy:

That for the purpose of further increasing the naval establishment of the United States the President is hereby authorized to have constructed by contract three seagoing coast line battle ships, carrying the heaviest armor and most powerful ordnance for vessels of their class upon a trial displacement of about thirteen thousand five hundred tons, to be sheathed and coppered, and to have the highest practicable speed and great radius of action, and to cost, exclusive of armor and armament, not exceeding three million six hundred thousand dollars each; three armored cruisers of about twelve thousand tons trial displacement, carrying the heaviest armor and most powerful ordnance for vessels of their class, to be sheathed and coppered, and to have the highest practicable speed and great radius of action, and to cost, exclusive of armor and armament, not exceeding four million dollars each; and six protected cruisers of about two thousand five hundred tons trial displacement, to be sheathed and coppered, and to have the highest speed compatible with good cruising qualities, great radius of action, and to carry the most powerful ordnance suited to vessels of their class, and to cost, exclusive of armament, not exceeding one million one hundred and forty-one thousand eight hundred dollars each; and the contracts for the construction of each of said vessels shall be awarded by the Secretary of the Navy to the lowest best responsible bidder, having in view the best results and most expeditious delivery; and not more than two of the seagoing battleships and not more than two of the armored cruisers herein provided for and not more than two of the protected cruisers herein provided

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for shall be built in one yard or by one contracting party; and in the construction of all said vessels all of the provisions of the Act of May fourth, eighteen hundred and ninety-eight, entitled "An Act making appropriations for the naval establishment for the fiscal year ending June thirtieth, eighteen hundred and ninety-nine, and for other purposes," shall be observed and followed; and subject to the provisions hereinafter made, one and not more than one of the aforesaid seagoing battleships, and one and not more than one of the aforesaid armored cruisers shall be built on or near the coast of the Pacific Ocean or in the waters connecting therewith: *Provided*, That if it shall appear to the satisfaction of the President of the United States, from the biddings for such contracts when the same are opened and examined by him, said vessels, or either of them, can not be constructed on or near the coast of the Pacific Ocean, at a cost not exceeding four per centum above the lowest accepted bid for the other battleships or cruisers provided for in this Act, he shall authorize the construction of said vessels, or either of them, elsewhere in the United States, subject to the limitations as to cost hereinbefore provided.

Of these, only the six protected cruisers have as yet been outlined in plans, and proposals will very soon be invited from builders. These six cruisers will be known as the *Denver*, *Des Moines*, *Chattanooga*, *Galveston*, *Tacoma* and *Cleveland*, and will be about 292 feet long by 43 feet beam. They will have a displacement of 3,100 tons each and a speed of 16½ knots. Their bunkers will have a coal capacity of 700 tons, giving a steaming radius at 10 knots per hour of about 6,000 knots. The hulls will be sheathed and coppered with a view to obviating the necessity for frequent docking, especially while on distant foreign stations. The principal characteristics as far as yet determined, are embraced in the following description of one of this class.

The vessel will be provided with a water-tight deck extending from stem to stern; the sides sloping and joining the vessel's side below the water line. A belt of cellulose of approved type, extending the entire length of the vessel at the water line and above the water-tight deck, will be provided.

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The vessel will have a flush upper deck, with hammock berthing extending from about the fore to the main mast, the extremities to be fitted with portable rails to be let down so as to give an unobstructed fire to the main battery guns to be mounted on the upper deck.

No wood work is to be incorporated in the hull or fittings except such as is indispensable.

The spar deck only is to be of wood, and this is to be laid on a complete metal deck.

The lower decks will be covered with linoleum or other approved covering.

All wood work used in the construction of the hull, except the underwater external sheathing, is to be fireproofed by a process satisfactory to the Department.

The main battery will consist of ten 5-inch guns of 50 calibers in length, mounted as follows: One forward and one aft on the midship line on the upper deck, and four on each side on the deck below; the forward pair of guns to train from right ahead to 45 degrees abaft the beam; the after pair of guns to train right astern to 45 degrees forward of the beam; the four waist guns to train 45 degrees forward and abaft the beam. Provision must be made for securing all the gun-deck guns in a nearly fore-and-aft position, thus leaving an unobstructed side.

The secondary battery will consist of not less than eight 6-pounder R. F. guns; two 1-pounders and four machine guns, so disposed as to give a large arc of fire; also one field gun.

The weight of this battery, with its mounts and accessories, will be about 98 tons. The weight of ammunition to be carried will be about 153 tons.

The propelling engines will be rights-and-lefts placed in separate water-tight compartments. They will be of the vertical, inverted-cylinder, direct-acting, triple-expansion type, each with a high-pressure cylinder 18 inches, an intermediate-pressure cylinder 28¾ inches, and two low-pressure cylinders 35½ inches in diameter, and stroke of all pistons being 30 inches. The collective indicated horse-power of propelling and circulating-pump engines will be 4,500 when the main engines are making about

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172 revolutions per minute, with a steam pressure of 275 pounds in the boilers, reduced to 250 pounds at high-pressure cylinders. The propelling engines will be placed in water-tight compartments.

The sequence of the location of the four cylinders from the forward part of the vessel will be as follows: First low-pressure, high-pressure, intermediate-pressure, second low-pressure. The main valves will be of the piston type for the high-pressure and intermediate-pressure cylinders, and the low-pressure cylinders will have slide valves, all worked by Stephenson link motion with double bar links.

The valve gears will be made interchangeable as far as practicable. There will be one piston valve for each high-pressure cylinder and two for each intermediate-pressure cylinder, and one slide valve for each low-pressure cylinder. Each main piston will have one piston rod, with a crosshead working on a slipper guide. The framing of the engine will consist of forged-steel columns in front and back. The engine bed plates will be cast steel. The crank shaft for each engine will be forged in two pieces, the shaft for the forward low-pressure and the high-pressure cylinders forming one piece, and the intermediate-pressure and the after low-pressure cylinders forming the other piece. All crank, thrust and propeller shafting will be hollow. Any other system of balancing the rotating and reciprocating parts will be taken into consideration by the Bureau of Steam Engineering. The shafts, piston rods, connecting rods, valve rods, eccentric rods and working parts generally will be forged nickel-steel.

There will be a vertical, single-acting air pump working from the crosshead of the forward low-pressure cylinder. The main circulating pumps will be of the centrifugal type, one for each main condenser. The two auxiliary condensers will have about 450 square feet of cooling surface each, and will have combined air and circulating pumps.

The propellers will be rights-and-lefts, of manganese bronze or approved equivalent material. They will turn from the ship.

There will be six water-tube boilers, aggregating about 4,700 horse-power, constructed for a working pressure of 275 pounds

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per square inch. The total grate surface will be at least 300 square feet, and the total heating surface about 13,200 square feet. The boilers will be in two compartments, with fire rooms athwartships. There will be two smoke pipes for all the boilers.

The forced-draft system will consist of three blowers discharging into air-tight fire rooms. The air for combustion will be heated by the hot gases circulating among or through tubes arranged in the uptakes or in the upper part of boiler casing, and will be conveyed through ducts fitted with dampers to closed ash pits.

There will be steam reversing engines, ash hoists, turning engine, auxiliary pumps, engine for workshop machinery, evaporators and distillers, and such other auxiliary or supplementary machinery, tools, instruments or apparatus as may be necessary.

The Bureau has not yet determined which of the leading types of water-tube boilers will be fixed upon for the new ships. Three plans of batteries are in course of preparation, involving the use of the Thornycroft, the Babcock & Wilcox and the Niclausse.

The following auxiliary machinery, in addition to that pertaining to the main engines and their dependencies, is to be supplied and is to be operated by steam power, viz:

Steam steering engine.

Anchor engine, with capstan above.

Four deck winches, or two combined, giving two hoisting drums at each side of the deck.

Two ash hoists from each fire room—one on each side.

Dense-air ice machine, of approved type, with capacity of one ton per day.

Engine for running machine tools in general workshop.

Evaporating and distilling plant in two units, each having a capacity of 4,000 gallons per day.

The following auxiliary machinery is to be supplied and will be electrically operated, viz:

Blowers for hull ventilation.

Two electric winches for hoisting ammunition.

The following machine tools of approved make and design will

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be furnished and installed in the general workshop with proper shafting, countershafting, spare parts and tools:

One screw-cutting gap lathe as large as can be accommodated.

Two screw-cutting gap lathes of convenient size.

One drill press for drills up to 1½ inches.

One column shaper about 15 inch stroke × 24 inch traverse.

One emery grinder, two 12 inch × 2 inch wheels, one wheel fitted with surface table.

One large grindstone. One sensitive drill.

Six bench vices with pipe holder and other fittings.

SUMMARY OF PRINCIPAL WEIGHTS—DEPARTMENT'S DESIGN.

	Tons.
Guns, mounts, shields, etc., about,	98
Ammunition, ordnance stores and outfit, about,	155
Machinery, complete, about,	405
Engineer's stores, about,	22
Fresh water for steaming purposes,	40
Total coal,	700
Boats and outfits,	13
Masts and spars,	14
Electric plant and electric outfit,	29
Equipment, including anchors, chains, rigging, etc.,	72
Officers, crew and outfit,	37
Miscellaneous and provisions and clothing stores,	92

In advertising for proposals the Secretary of the Navy will divide the bids into two classes, Class I being as follows:

For the construction of the hull and machinery of each of said vessels, including engines, boilers and their appurtenances and spare parts, and for the equipment complete in all respects except as hereinafter stated, and for the installation of ordnance outfit in accordance with the plans and specifications provided by the Secretary of the Navy.

Class II of the bids will cover exactly the same ground except that the plans and specifications, instead of being provided by the Secretary of the Navy, will be submitted by the bidder.

Albany.—The recent launch at the yard of Armstrong, Whitworth & Co., at Elswick, England, of the cruiser *Albany*, build-

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ing for the United States Government, has served to again call attention in marine and naval circles to this vessel and her sister ship, the *New Orleans*, which has been in commission for some time. These are vessels purchased during the late war. There is not in the Navy of the United States any other vessels of exactly similar type, and the armament of these British-built cruisers is also in the nature of a decided innovation to American naval men.

The *Albany* and *New Orleans*, which are exactly identical in almost every particular, are classed as unarmored steel vessels—protected cruisers sheathed with wood. They are each 358 feet over all, 330 feet on the water line, 43 feet 9 inches beam, 16 feet 10 inches depth and of 3,437 tons displacement. Tonnage is 2,174 gross or 1,224 net, and their 7,500 maximum indicated horse-power gives them a speed of 20 knots. The normal coal capacity is 700 tons and the bunker capacity 800 tons. The maximum draught aft at the lowest point of keel, with the ship ready for sea, with bunkers full, is 20 feet 2 inches.

These vessels have protected steel decks, extending fore and aft from stem to stern, and are fitted with fourteen water-tight bulkheads extending up to the berth deck. In addition to these subdivisions there are double bottoms, minutely subdivided into water-tight compartments, and the store rooms and coal bunkers below the protected deck are also water tight. The protective deck is 1¼ inches thick on the flat and at the ends, and 3½ inches thick on the slopes for the length of the machinery and magazines, with 4-inch glacis plates around the funnel hatches.

Interest felt in these cruisers in the United States has been especially manifest in the matter of armament, which some naval officers have declared is superior to that to be found on any similar vessels in our Navy. The main battery consists of six 6-inch rapid-fire guns—one on the poop, one on the forecastle and four on the broadsides—and four 4.7-inch quick-firing guns on the broadsides. The secondary battery consists of ten 6-pounder, rapid-fire guns, two under the forecastle, two under the poop, two on the forecastle, two on the poop and two on the bulwarks; four 1-pounder, rapid-fire guns in the lower tops, four Maxim

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guns in the upper tops, two 2-pounder field guns and three torpedo tubes. The field guns are for use in the boats and in landing. As indicated by the accompanying illustration there are two military masts with two tops in each mast.

The propelling machinery, being built for the *Albany* by Messrs. Hawthorn, Leslie & Co., Ltd., at their St. Peter's works, consists of two sets of triple-expansion engines, driving twin screws, the maximum indicated horse-power being 7,500 at 160 revolutions per minute. The diameter of the high-pressure cylinder is 31 inches, intermediate, 46 inches, and the low-pressure, 70 inches, the stroke of all being 30 inches. The propellers are of composition, three-bladed, the blades being separate and secured to the hub by bolts. The diameter of propellers is 12 feet, and the pitch 15 feet 9 inches, variable 1 foot in either direction. The total area of the three blades is 40 square feet. The air pumps are worked off the low-pressure crosshead, the circulating pump being of the cylindrical type, worked by an independent engine. There are two main condensers, each having a total cooling surface of 4,500 square feet. The air pumps are 22 inches in diameter by 14 inches stroke. The main engines are placed abreast of each other, and are separated by a water-tight fore-and-aft bulkhead. In the starboard engine room there is an auxiliary condenser, with a centrifugal circulating pump and vertical air pump, worked by a common engine, for the use of the auxiliary machinery in port. There are four double-ended Scotch boilers, each 12 feet 3 inches in diameter and 18 feet long, with three furnaces at each end; the boilers being placed in two water-tight compartments, with fire rooms at each end. The steam pressure is 155 pounds to the square inch. There are eight forced-draft blowers for the purpose of supplying air to the furnaces when the fire rooms are closed. The total grate surface is 468 square feet, and the total heating surface 13,156 square feet. There is one main feed and one auxiliary feed pump in each boiler compartment. Half of the double bottom under each of the boiler compartments is fitted for use as a reserve feed-water tank. In each engine room there is one auxiliary pump for use on the bilges, fire main and water surface. In addition

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to the above, the vessel is lighted by electricity, the plant consisting of three dynamos and engines. There is also a distilling plant, with a capacity of about fifty tons per day. There is a steam capstan and steam steering engine, and there are ventilating blowers and ash hoists.

Both cruisers, it will be remembered, were purchased from the Brazilian Government on March 16, 1898, just at the opening of the Spanish-American war. The representatives of the United States did not wish to purchase the *Albany* for the reason that she was not near completion, but Brazil would not sell unless both vessels were taken, and this Government was very desirous of securing the cruiser which is now the *New Orleans*. The latter vessel went into commission two days after the date of sale, having been launched on December 4, 1896, and came at once to this country, where she was in service throughout the war. The *Albany*, having been launched January 14, will probably be ready in a short time for her trial trip. The complement of each vessel is 24 officers and 383 men.—"Marine Review."

Progress on New War Vessels.—Reports concerning the progress in construction of new vessels for the United States Navy now in hand at various yards, have been compiled for the month of April. They show that the battleship *Kearsarge* is within 10 per cent. of leaving the builder's hands, and the *Kentucky* is only 2 per cent. behind. Both these vessels are being built at Newport News, where the *Illinois*, with 65 per cent. of work done, is also under construction. Of the two battleships at the Cramp yards the *Alabama* is within 18 per cent. of completion, and the *Maine*, on which work has just started, has 4 per cent. of work done. The *Wisconsin*, at the Union Iron Works, San Francisco, has 67 per cent. to her credit, while the *Ohio*, at the same yards, has not been started. One per cent. of work has been done on the *Missouri*, sister ship of the *Ohio* and *Maine*, at Newport News. The sheathed cruiser *Albany*, purchased from Brazil, is four-fifths completed at the Armstrong yards in England. Work has started on three of the four monitors provided for in last year's appropriation bill. Of the sixteen torpedo-boat destroyers re-

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cently provided for, the *Hopkins* and the *Hull*, at the Harlan & Hollingsworth Works, Wilmington, Del., are in advance of all the others, with only 17 per cent. of work done. The torpedo boat *Dahlgren*, at the Bath Iron Works, Maine, is within 4 per cent. of completion. The *Craven*, at the same place, is next, with 92 per cent. The other fifteen torpedo boats range in progress from 6 per cent. to 75 per cent., with the exception of three on which work has not been begun. The *Chesapeake*, the sailing vsesel for naval cadets, lacks 22 per cent. of being finished, and the submarine torpedo boat *Plunger*, at the Columbian Iron Works, Baltimore, shows 85 per cent. of work completed.

ENGLAND.

New Vessels.—The four battleships recently ordered under the Supplemental Programme are intermediate in size between the *Formidable* and *Canopus* classes, and have practically the same armament as the *Formidable*, but are to have superior speed and thinner armor. They are to be known as the *Duncan* class.

The following are their principal features: Length between perpendiculars, 405 feet; breadth, extreme, 75 feet 6 inches; mean draught, 26 feet 6 inches; displacement, 14,000 tons; speed (with natural draft), 19 knots; I.H.P., 18,000. Armament: Four 12-inch breech-loading guns in two barbettes, twelve 6-inch Q.F. in casemates, twelve 12-pounder Q.F., six 3-pounders and four torpedo-tubes.

Stability and buoyancy will be secured by vertical side armor 7 inches thick extending over a considerable portion of the length, and continued in a gradually reduced thickness to the bow.

The barbettes for the 12-inch guns will have 11-inch armor, and the casmates for the 6-inch guns, 6-inch armor.

All armor will be of the latest and most improved quality, possessing much greater defensive power in proportion to its thickness than armor used in the *Majestic* class.

Belleville boilers, with economizers, will be fitted.

The speed of 19 knots exceeds that of preceding battleships in the Royal Navy, and is to be obtained on an eight hours'

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trial with natural draft in the stokeholds. For continuous steaming at sea in smooth water and with clean bottoms it is estimated that about 18 knots should be maintained.

The coal carried will be 900 tons at normal draught, and the bunker capacity will be 2,000 tons. In these respects the new ships are practically indentical with the *Majestic* and *Formidable* classes.

First-class Cruisers.—Of the eight vessels belonging to the *Diadem* class which were in hand at the beginning of 1898–99, two (the *Diadem* and *Niobe*) are in commission; the *Europa* has been for some time complete and in the Fleet Reserve; the *Andromeda* and *Argonaut* have completed their trials, and will be ready for service by the end of the present financial year.

The *Ariadne* has finished her steam trials and will be completed at an early date; the *Amphitrite* has been delivered by the contractors, and her trials will shortly take place. The *Spartiate* is being advanced at Pembroke. All these vessels will be ready for service in 1899–1900.

Six armored cruisers of the *Cressy* class are building by contract; two of these have been ordered in 1898–99, as part of the new programme of four armored cruisers included in the estimates of that year. The difficulties in the supply of materials greatly delayed their commencement, but good progress is now being made, and there is no reason to doubt that the contract dates for delivery will be kept.

Four large armored cruisers have been ordered recently, of which two belong to the original programme for 1898–99, and two to the supplemental programme. A general description of the designs was given to Parliament, when the latter programme was introduced in July, 1898. The type will be known as the *Drake* class. The following are their principal features: Length between perpendiculars, 500 feet; breadth, extreme, 71 feet; mean draught, 26 feet; displacement, 14,100 tons; speed (with natural draft), 23 knots; I.H.P., 30,000. Armament: Two 9.2-inch guns with armored shields, sixteen 6-inch Q. F. guns in casemates, fourteen 12-pounder Q. F. guns, three 3-pounders, two torpedo tubes.

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The 9.2-inch and 6-inch guns will be of the latest and most powerful types, with armor protection equal to that of the *Powerful* class. Buoyancy and stability will be secured by vertical side armor, about six inches thick, associated with strong steel decks, as in the *Canopus* and *Cressy* classes. The bows of the new vessels will be more strongly defended. The steel hulls will be unsheathed.

Belleville boilers, with economizers, will be fitted. Twin screws will be adopted. The speed of 23 knots is to be maintained for eight hours on the contractors' trials, with natural draft in the stokeholds. For continuous steaming at sea in smooth water 21 knots should be maintained. The coal-bunker capacity will be 2,500 tons, and 1,250 tons are to be carried at the speed trials.

One of these vessels is building at Pembroke, and the remaining three by contract.

Two other cruisers were included in the Supplemental Programme. They will be of a new design, and tenders have been invited for their construction. Their principal features are as follows: Length between perpendiculars, 440 feet; breadth, extreme, 66 feet; mean draught, 24½ feet; displacement, 9,800 tons; speed (with natural draft), 23 knots; I.H.P., 22,000. Armament: Fourteen 6-inch Q. F. guns (four in turrets, ten in casemates), ten 12-pounder Q. F. guns, three 3-pounders, two torpedo tubes.

The 6-inch guns will be of the latest type, and will be protected by armor about four inches thick. Vertical side armor of the same thickness will be carried over a considerable portion of the length, with thinner armor on the bows. Strong protective decks will be associated with this side armor. The steel hulls will be unsheathed.

Belleville boilers, with economizers, will be fitted. The speed of 23 knots is to be maintained for eight hours on contractors' trials. For smooth-water continuous steaming at sea about 21 knots should be maintained. The coal-bunker capacity will be for 1,600 tons, and 800 tons are to be carried on the speed trial.

Battleship Glory.—On March 11th Her Majesty's first-class

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battleship *Glory* was floated from Messrs. Lairds' shipbuilding yard at Birkenhead. Owing to the recent death of Mr. William Laird, the ceremony of floating was kept as quiet as possible, but a vast concourse of people had assembled to witness it. The usual service was read by the Rev. J. W. Hughes-Games, M. A., vicar of Birkenhead, and the vessel was christened by Mrs. John M. Laird, wife of the senior member of the builders' firm.

The *Glory* is of the *Canopus* class, designed by Sir William H. White, K. C. B., Director of Naval Construction, and as this class of vessel is now well known, we will offer only a short description. Her dimensions are: Length, 390 feet; breadth, 74 feet; mean draught, about 26 feet 6 inches; displacement, 12,900 tons; freeboard, forward, 22 feet 6 inches, aft, 19 feet; indicated horse-power, 13,500; speed, about 18½ knots; coal stowage, about 2,000 tons. The armor is of Harveyed steel, and there is a protective deck from the lower edge of the armor, covering the machinery, magazines, and other vital parts.

The ship is lighted throughout with an installation of about 750 electric lights, and equipped with six search lights of 30,000 candle power, each of which is capable of being worked by dynamos under protection. The officers and crew are accommodated on the main and belt decks. The upper deck extends from stem to stern without a break, and above it is a continuous bridge deck extending the whole length between the barbettes; on this deck are the conning towers surmounted by navigating bridges (which will be about 36 feet above water) and the chart-house. The masts, two in number, are built of steel, fitted with military and signalling tops, and are already in place and complete with their derricks for hoisting boats, etc.

The armament of the *Glory* will consist of four 12-inch 46-ton guns, mounted in barbettes, in pairs, and firing a projectile weighing 850 pounds, with a powder charge of 148 pounds. There are forty-three quick-firing guns in all, twelve 6-inch on the main and upper decks, mounted in casemates protected by 6-inch armor; twelve 12-pounders, six 3-pounder quick-firing, eight small machine guns, and five field guns. There are also four submerged torpedo tubes for 18-inch torpedoes.

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The main propelling machinery, constructed at the Birkenhead Iron Works, consists of two sets of engines of the triple-expansion inverted type of the latest design. Each set is placed in a separate engine room. The cylinders are: High pressure, 30 inches; intermediate pressure, 49 inches, and low pressure, 80 inches in diameter respectively, with a stroke of 51 inches. The boilers, twenty in number, are of the Belleville type (with economizers), working at a pressure of 300 pounds, and are placed in three water-tight compartments.

The *Glory* illustrates the advantage of building these large battleships in dock in preference to building them on a slip and launching them, as she floated out with all her citadel and casemate armor, and most of the barbette armor in place; indeed, all the armor plating would have been completed had it not been for the press of work in Sheffield rendering it impossible for armor-plate manufacturers to make delivery as early as required. A considerable portion of the boilers is on board. The whole of the auxiliary machinery is in place, and the pipes and connections are being fitted. The main engines are erected on board, with the exception of the cylinders, so that the vessel, as floated out from the building dock, is in a far more advanced state than would have been the case had she been launched in the ordinary way, her displacement on floating out being approximately 9,000 tons. This feature is brought into prominence at the present time, as Her Majesty's ship *Implacable*, of 14,900 tons displacement, for which the machinery of 15,000 horse-power is also being built by Messrs. Laird Brothers, was launched from Devonport on Saturday last, her weight being about 4,500 tons. It is expected that the *Glory* will be ready to hoist her pennant within six months, but the *Implacable* is not expected to be ready for commission for about fifteen months. The *Glory* will have a complement of 750 men.

Implacable.—The first-class battleship *Implacable* was launched at Devonport on March 11th. She is of the same type as the *Formidable*, which was launched at Portsmouth in November last, and the *Irresistible*, launched at Chatham in December. Her principal dimensions are as follows: Length between per-

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pendiculars, 400 feet; beam, 75 feet; load draught, 26 feet 3 inches forward, 27 feet 3 inches aft; load displacement, 15,000 tons. The side armor will consist of Harveyized steel 9 inches thick, joined by two armor bulkheads, thus forming a complete belt round the vital portions of the ship. There will be two protective decks, one being on the turtle-back principle, which will start from the lower edge of the armor belt. The main armament will consist of four 12-inch wire guns of a new and improved type, mounted in pairs in two barbettes protected by 12-inch armor. There will also be twelve 6-inch Q. F. guns of a new type, mounted in casemates protected by 6-inch armor; besides, sixteen 12-pounder Q. F. guns, six 3-pounder Hotchkiss Q. F. guns, and eight Maxim guns. The vessel will be fitted with four submerged torpedo tubes 18 inches in diameter. Her engines, which are being made by Messrs. Laird Bros., of Birkenhead, are of the triple-expansion type, and will develop 15,000 horse-power, and there will be twenty water-tube boilers on the Belleville principle. When in commission she will have a total complement of 773 officers and men.

English Torpedo Boat Trials.—The London correspondent of the "Glasgow Herald" furnishes some interesting results of trials of torpedo-boat destroyers during the year 1898, and in opening his article briefly notes the extent of the progress made with the fleet of boats ordered. There were, he says, forty-two in the first fleet of 27-knot boats, and three of these, by White, of Cowes, passed through their trial with about a tenth of a knot to spare, although the power was somewhat abnormal, between 4,800 and 5,070 indicated horse-power. Two, built at Paisley, have yet to pass through the ordeal—they are being fitted with water-tube boilers; and the others have had long periods of commission, and have done well, although water-tube boilers have had to be ordered for some of the first, which had locomotive boilers. Fifty-four faster vessels were ordered, including four of 32 knots or more, the *Arab* from Clydebank, the *Alabatross* from Thornycroft, the *Express* from Laird, and the *Viper* from Fairfield. The other fifty were to steam 30 knots, and of these fifteen have passed through their trial during the year just closed, fourteen succeeded

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the previous year, and there remain twenty-one of the 30-knot and the four faster boats still to try, of which five have not yet been launched. Last year Laird, Fairfield and Palmer each passed three through their runs. Vickers, of Barrow-in-Furness, Doxford, of Sunderland, and Thornycroft, of London, have each succeeded in the trials of two boats. The power necessary has varied very much. The lowest was with one of Thornycroft's boats, 5,892 indicated horse-power, which gave almost the highest speed got, 30.4 knots; while Vickers, with the *Avon*, about equaled this with 5,986 indicated horse-power and 30¼ knots, the sister boats from the Barrow works doing 30.35 knots for 9,412 indicated horse-power.

The highest power was registered in one of Lairds' boats, which developed 7,090 indicated horse-power, and only got a small fraction over 30 knots. Another of the same builders' boats registered 6,848 indicated horse-power for 30.16 knots; but a third made 30¼ knots for 6,146 indicated horse-power. Thornycroft's powers are low; the others, with one or two exceptions, range about 6,000 indicated horse-power upwards. The highest speed last year was with the *Aerial*, Thornycroft's boat, 30.6 knots; next Palmer's *Flying Fish*, 30.48 knots; Palmer's *Fawn*, 30.46 knots; Thornycroft's *Angler*, 30.40 knots; Barrow's *Bittern*, 30.35 knots; Fairfield's *Osprey*, 30.31 knots; Lairds' *Wolf*, 30.26 knots; Vicker's *Avon*, 30.25 knots, and Fairfield's *Gipsy* and *Fairy*, 30.20 knots. As to coal consumption, the lowest return was in the case of the *Aerial*, 2.02 pounds; but this was exceptional, and, moreover, extreme accuracy in this respect under the trying conditions is difficult of attainment. As a rule, the slightest fraction under the stipulated 2½ pounds is satisfactory, and in one or two cases it was more, necessitating an extra load, which placed some of the ships at a slight disadvantage as to speed. Two of the 32-knot boats have had frequent preliminary trials, but none have pulled off their speed. The *Albatross* has done 31¼ with 7,500 indicated horse-power, and it is hoped 32 knots will be got; but it will probably need more than the assumed 8,000 indicated horse-power, which means a piston speed of 1,340 feet per minute, with over 4,000 revolutions per

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minute. Meanwhile Yarrow has passed through a preliminary trial the first of his Japanese boats, and got 31 knots for a trifle over 6,000 indicated horse-power.

The French Shipbuilding Programme.—The vessels of all classes to be completed, carried forward, or begun in 1899 number 108, and include seven battleships, thirteen armored cruisers, and eight protected cruisers. Practically seventeen vessels on the list are already out of hand, or will be before the close of 1899—the battleships *Charlemagne* and *Gaulois*, the first-class cruiser *Guichen*, the second-class cruiser *Protet*, the despatch vessel *Kersaint*, the torpedo-boat destroyers *Dunois* and *Durandal*, the seagoing boat *Cyclone*, and nine first-class boats. Of the ninety-one other vessels, sixty three were in hand on December 31, 1898, and during 1899 the following will be completed: The battleship *Saint Louis* (April), the armored cruiser *D'Entrecasteaux* (now actually completing her trials), the first-class cruiser *Châteaurenault*, the third-class cruisers *D'Estrées* and *Supernet*, the torpedo-boat destroyers *Hallebarde*, *La Hire*, *Fauconneau*, *Espingole*, *Pique*, *Epée*, *Framée* and *Yatagan*, the gunboat *Decidée*, the submarine boat *Morse*, seventeen first-class torpedo boats and six vedettee boats for the transport *Foudre*. The vessels to be finished in 1900 are the battleships *Henry IV* and *Iéna*, the first-class cruiser *Jurien de la Gravière*, the gunboat *Zélée*, the submarine boat *Narval* and the sea-going torpedo boats *Siroco*, *Mistral*, *Simoun*, *Typhon*, *Trombe* and *Audacieux;* in 1901 the battleship *Suffren*, the armored cruisers *Jeanne d'Arc*, *Gueydon*, *Dupetit-Thouars*, *Montcalm*, *Desaix* and *Kleber*, the transport *Vauclause* (long at a standstill), and torpedo boat *No. 242* (*Saigon*); in 1902 the armored cruisers *Condé*, *Gloire*, *Dupleix* and *Sully*, and torpedo boat *No. 244* (*Saigon*). In addition to these, the ships proposed to be laid down in 1899, are twenty-eight in number, as follows: One first-class battleship *A 8*, two first-class armored cruisers, *C 9* and *C 10;* two dispatch-cruisers (*croiseurs estafettes*) *H 4* and *H 5;* two torpedo-boat destroyers, *M 8* and *M 9;* four squadron torpedo boats, *N 18* to *N 21;* eleven first class torpedo boats, *P 64* to *P 74*, and six submarine boats, *Q 5* to *Q 10*. The date of completion of these twenty-eight vessels is not yet settled,

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except the two torpedo-boat destroyers, which are to be finished by 1902. The following vessels are to be constructed at the various dockyards:

At Brest.—Battleships *A 8*, armored cruiser *C 9* and submarine boats *Q 6* and *Q 7*.

At Rochefort.—Cruiser-dispatch vessel *H 4* and submarine boats *Q 9* and *Q 10*.

At Cherbourg.—Submarine boat *Q 5*.

Lorient.—Submarine boat *Q 8*.

The remaining vessels are to be built at private yards.

The plans of the new battleship *A 8* are not yet completed and no fixed sum appears in the estimates for her.

The armored cruisers *C 9* and *C 10* are to be of the *Gloire* type, having a displacement of 10,014 tons, a length of 448 feet 6 inches, with a beam of 60 feet; there will be three screws; the engines are to develop 20,500 I.H.P., giving a speed under forced draft of 21 knots; at this speed with a coal supply of 1,500 tons, they will have a radius of action of 1,940 miles, and of 10,400 miles at 10 knots speed. The armament will consist of two 19.4-centimeter (7.6-inch) guns, eight 16.4-centimeter (6.3-inch) Q. F. and six 10.1-centimeter (3.9-inch) Q. F. guns, with eighteen 3-pounders, six 1-pounders, and two machine guns; there will also be four torpedo discharges, two being submerged. The cost of *C 9* will be 21,715,641 francs, and of *C 10* (to be built by contract) 23,573,500 francs.

The two cruiser dispatch vessels, which are of quite a new type, will be of the following dimensions: Length, 390 feet; beam, 42 feet 3 inches, with a displacement of over 4,000 tons. The engines are to develop 15,000 I.H.P., giving a speed of 23 knots, steam being supplied by water-tube boilers. The radius of action will be 8,000 miles at 10 knots, and 1,330 miles at full speed. Their armament will consist of eight 10-centimeter (3.9-inch) guns, twelve 3-pounder Q. F. guns, and four 1-pounder Q. F. guns, with four torpedo discharges, two being submerged. The cost of *H 4* (to be built in the dockyard) will be 8,766,468 francs; that of *H 5* (to be built by contract) 8,731,518 francs.

The six submarine boats will be of the *Narval* type, at pres-

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ent under construction at Cherbourg. They will have a displacement of 106 tons, with a length of 110 feet 6 inches, and a beam of 11 feet 3 inches. They will be driven by a single screw, the engines developing 217 horse-power, steam being provided by water-tube boilers; the speed is to be 12 knots. They will have four torpedo tubes. Their crew will consist of two officers and nine men, and each boat will cost 648,050 francs.

Fifteen battle and coast-defense ships in the French Navy are undergoing radical changes in their refits, which consists in taking out the ordinary marine boilers and replacing them with water-tube boilers, and substituting guns of smaller caliber but greater power. The secondary batteries are likewise improved, gun positions altered and superstructure reduced. The sum of $5,299,543 has been voted for this purpose, to be expended by the year 1900, up to which time the following ships will have been modernized as far as possible: *Formidable*, *Courbet*, *Redoubtable*, *Admiral Baudin*, *Hoche*, *Marceau*, *Dévastation*, *Neptune*, *Admiral Duperre*, *Magenta*, *Caiman*, *Requin*, *Terrible*, *Indomptable* and *Furieux*. The *Admiral Baudin* will have 12-inch guns in turrets, instead of, as at present, fourteen 6-inch in barbette.

GERMANY.

Torpedo Boat.—Another claimant for the honors of the fastest vessel afloat has appeared in the famous German builder, F. Schichau, of Elbing, who has turned out a torpedo-boat destroyer with the astounding rate of speed of 35.2 knots. An account of this boat is here reproduced from our German contemporary "Ueberall." In land miles the speed is equivalent to 40.55 miles an hour, or little less than many limited railroad trains. A translation of the article reads:

"Since the appearance of the first torpedo boats, twenty years ago, the speed of this type of boat has been increased the rate of about a knot a year. The first small English torpedo boats did not make more than 15 knots, and to-day the latest torpedo-boat destroyers built in Germany have reached a speed of 35.2 knots. The foreign-built boats of the same class built in 1898, on the contrary, have barely exceeded 30 knots on their trial

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trips, with the exception of the English trial torpedo boat *Turbinia*, built last year, which is said to have reached a speed of 32.75 knots. This boat is equipped with three steam turbines, each of which drives a shaft with three propellers, making a total of nine propellers. This great number of propellers is rather cumbersome, but the greatest disadvantage of the *Turbinia* lies in the fact of her inability to make any speed going astern.

"The new torpedo-boat destroyer belongs to a series of four boats built for the Chinese Navy by F. Schichau, of Elbing, last summer. Each boat has twin triple-expansion engines, each driving one propeller. Fully equipped, and with 67 tons of coal on board, these Schichau torpedo-boat destroyers made a speed of 33.6 knots, which is one knot faster than the *Turbinia* when the latter was light, and the Schichau boats ran 35.2 knots when light, exceeding the speed of the *Turbinia* by 2½ knots. The speed of 35.2 knots per hour represents a speed of 65.2 kilometers, and on the continent there are in Germany only eighteen, in Austria and France three each, and in Belgium only one express train which exceed this speed.

"The latest results have demonstrated that the German builders have at last succeeded in outstripping all foreign competition in the construction of these speedy boats."

It will be some consolation to the navies of the civilized powers that these boats are for China. With Chinese crews and Chinese methods it is doubtful if the trial speeds will be attained in actual service.—"Marine Engineering," March, 1899.

JAPAN.

Asama.—The Japanese belted cruiser *Asama* left the Tyne on the 7th of February, and after running a short time at easy speed, with only four boilers in use, she anchored in about twenty fathoms of water, four miles off the coast, in order to test the working of those anchors and cables which had not been used during her recent trip to dock at Chatham. The gear worked satisfactorily. On the 8th of February the weather was hazy over the land and the towers marking the measured course were obscured, but the cruiser ran to sea for six hours at full power

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of natural draft, with open stokeholds. The horse-power developed was rather over 13,000, giving 140 to 142 revolutions per minute, and a speed by log averaging 20.37 knots. The forced-draft trials were delayed by thick weather and strong winds till February 11th, when, with a moderate sea but a strong beam wind off the land, the engines worked up to 19,000 horse-power, with 158 revolutions and a mean speed for the vessel of 22.07 knots. The engines, manufactured by Messrs. Humphrys and Tennant, worked absolutely smoothly. The *Asama* is the twelfth vessel the Japanese possess built at Elswick, but these were not all purchased. There are many points in her of considerable interest. Both engines are supplied with steam from cylindrical boilers placed back to back and stoked from the wings, and they give 13,000 horse-power without forced draft, and 18,000 with two inches of air pressure. The guaranteed speeds are 20 knots at the lower and 21¼ at the higher power, but these speeds were exceeded in practice. The boilers are worked at 150 pounds pressure, and the engines have a comparative short stroke so as to keep the whole of the cylinders below the armored deck, which is two inches thick, and extends to the ends of the ship. The propellers work outwards, and vibration is small at all speeds. The high and intermediate cranks are set at an angle of 170 degrees, the two low-pressure cylinder pistons having cranks at the same angle, one from the other, but the mean line of the latter is at right angles to the mean line of the high and intermediate cranks. The vessel's coal stowage is 700 tons normal and 1,450 tons can be carried, all in bunkers, and this larger quantity may be considerably increased by temporary means without impairing the seagoing qualities of the vessel.

Her armament includes four 8-inch quick-firing guns, mounted by pairs, one pair forward and one aft, in gun houses of 6-inch Harveyed steel, with an inner skin of an additional inch, and a flat cover, 1 inch thick, with three sighting cowls rising about a foot above the cover. The ammunition lifts open directly into the turrets. The guns in the forward turret are 25 feet above the water line, and the after guns 24 feet. There are fourteen 6-inch quick-firing guns, disposed as follows: Ten are

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in casements of 6-inch Harveyed steel, two on either side forward and two on either side aft, in pairs over one another, with one more gun on either side of the main deck, each in an isolated casemate. The remaining four are behind shields, as upper-deck mountings. The lower tier of sponsoned guns is 12½ feet above the water line, the upper about 20 feet. In addition to the above, twelve 12-pounders, and seven 1½-pounders, available for boat or land service, are in various parts of the ship. During the gun trials both pairs of the 8-inch guns were fired directly either ahead or astern with 5 degrees elevation and no injury was done. The four 6-inch guns forward were fired simultaneously and also those aft, the boats, woodwork and other fittings of the vessel being uninjured. All guns were fired with full charges. The defensive armor, including the armored decks, is stated to weigh 2,100 tons, and is thus disposed: A belt of 7-inch Harveyed steel, 7 feet deep, is along the water line, 2 feet above it and 5 feet below; this belt tapers to 3½ inches at the ends of the vessel. Above the 7-inch belt is another of 5 inches thickness, which reaches beyond the turrets at either end, and is then bent inwards and across, forming complete athwartship bulkheads, protecting the bases of the turrets and generally shielding the vessel against raking projectiles; a belt of 6-inch plating, which extends 25 feet aft from the stem on either side, protects the bow torpedo tube.

The *Asama* is supplied with four under-water torpedo tubes in addition to the one above water forward, and all are intended for torpedoes of 18-inch caliber. The main deck is in two thicknesses, each of ½-inch steel, and the ammunition lifts, where they rise above the belts, are circular tubes of 3-inch steel. The upper deck is covered with teak, and this is practically the only woodwork that cannot be disposed of in case of action or fire. The fire main is completely under the armored deck, and has risers at intervals, each with its own valve, so the accidents which occurred in the Spanish ships at Santiago, from the destruction of their fire mains, are guarded against. The bulkheads are of steel, and the doors and cabin fittings alone are of wood. A flat, 2-inch steel plate runs horizontally forward to strengthen the

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lower portion of the ram, whose upper side is adequately strong from the support afforded by the continuance of the armored deck right up to the stem. Her length is 408 feet, with 67 feet beam, and a mean draught of 24 feet 8 inches, with the normal supply of coal on board. At this draught it takes 40 tons to sink her one inch.—"Engineering," February, 1899.

PORTUGAL.

Don Carlos I.—The Portuguese cruiser *Don Carlos I*, which has been constructed by Sir W. G. Armstrong, Whitworth and Co., Limited, has completed her official trials. This vessel is 360 feet long, 46 feet broad, 17 feet 6 inches mean draught and of 4,100 tons displacement. Her armament consists of four 15-centimeter guns, eight 12-centimeter guns, twelve 47-millimeter guns, six 37-millimeter guns, four mitrailleuses and five torpedo guns, and she has an armored deck with sloping sides of 4-inch armor. An interesting feature in connection with this vessel is that steam is provided by twelve Yarrow boilers; and at her steam trials an exceedingly good performance was obtained. For six hours with ½ inch of air pressure about 8,000 horse-power was developed and a mean speed of 20.64 knots obtained; and during her forced-draft trial, with a pressure not exceeding 2 inches, a power of 12,690 horses was realized and a mean speed of 22.15 knots was obtained in a considerable sea and half a gale of wind. It was recognized that with a smooth sea and no wind the vessel could easily have steamed 22½ knots. The gunnery trials passed off without a hitch of any kind.—"Engineering."

RUSSIA.

New Ships.—The following are the particulars of the twin-screw cruiser ordered at the Forges et Chantiers de la Méditerranée, at La Seyne, near Tulon: Displacement, 7,800 tons; extreme between perpendiculars, 445 feet; extreme beam, 57.1 feet; and draught amidships, 22.1 feet. The hull is being constructed at the yard at La Seyne, the engines at Marseilles, and the boilers at St. Denis, at the works of Messrs. Delaunay, Belleville & Co. When ready, besides a six hours' trial at 14

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knots, she will have a twenty-four-hour continuous trial at full power of her engines, when a speed of 21 knots is to be maintained. The expenditure of coal at 14 knots is to be only 1 kilogramme, and at 21 knots 1.15 kilogrammes. If the speed bargained for is not attained, the company will be liable to a fine of 10,000 francs for every tenth of a knot deficient under 21 knots, and the Government have the right of refusal, if the speed falls below 20 knots. The whole cost is to be 16,500,000 francs. There is to be an armor belt of 200 millimeters (8 inches) tapering to 100 millimeters (4 inches) in thickness, while the thickness of armor on the turrets will be 200 millimeters (8 inches). The electricity will be furnished by nine dynamos in three groups, each developing 80,000 watts at 100 volts, and will be used for working the turrets, the ammunition hoists, steering apparatus and pumps. There are two vertical triple-expansion engines giving at 140 revolutions a total of some 16,500 I.H.P. There will be an 8-inch gun in each of the two turrets, one forward and one aft, and in the casemates and battery deck eight 6-inch and twenty 3-inch Q. F. guns, besides machine guns and torpedo tubes. The bulkheads of the cabins are to be of steel, and all fittings of metal.

A battleship of 12,900 tons is also being built for the Russian Government at the same yard, of which the following are the chief dimensions: Length between perpendiculars, 388 feet 9 inches; extreme beam with armor, 75 feet 5½ inches; depth, 47 feet 11 inches; draught (on even keel), 26 feet; I.H.P., 16,300. Normal coal supply, 800 tons; entire capacity of bunkers, 1,350 tons. She is to be built to make 18 knots for 12 hours on end, the contractors being liable to a fine of 20,000 francs for every tenth of a knot deficient. Expenditure of coal at 12 knots, 1 kilogramme, and at 18 knots, 1.15 kilogrammes. Armament: Four 12-inch guns in pairs in turrets, twelve 6-inch Q. F. guns in pairs in broadside turrets, twenty 75-millimeter Q. F. guns (12-pdrs.) on the gun and upper decks, twenty-eight Q. F. guns of small caliber, and four torpedo tubes above the water line. She is to cost, with her armament and all complete, 30,282,000 francs. Electricity will be used for revolving the 12-inch and 6-inch gun tur-

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rets. She is to be built after the model of the French *Jauréguiberry*, and to have two principal engines with triple expansion.

As regards the cruisers ordered in Germany, the one ordered at Elbing, with an armored deck, has an extreme length of 347 feet 10 inches, and extreme beam of 40 feet, and is to have a guaranteed speed of 25 knots. She is to have three triple-expansion engines, supplied with steam from twelve Schichau boilers in three groups and three funnels. The armored deck is to reach 1.3 meters below the water line, the plates of the curved part being 50 millimeters, and of the horizontal 30 millimeters. She is to cost, without armament, 2,870,000 roubles, and to be ready in September, 1900.

The cruiser ordered at the Germania Works is to have a speed of 23 knots, and to be ready in July, 1900. At the Vulcan Works, near Stettin, a 23-knot cruiser has also been ordered, to be ready in August, 1900. The plans are still, however, under consideration.

Of the four torpedo vessels christened *Kit*, *Skat*, *Delphin* and *Kasatka*, which are in course of construction at the Schichau Works at Elbing, one is to be ready by the 1st January, 1900, and the other about June in the same year. Their dimensions are as follows: Length, 200 feet 2 inches; beam 23 feet, and draught (at stern post), 11 feet 9¾ inches; displacement, 350 tons. They will all have twelve water-tight bulkheads on the upper deck, and their hulls will be built of sheet steel with a zinc coating, varying in thickness from 7 to 4½ millimeters, the steel to have a resisting power of from 35 to 40 tons to the square inch (English), and an elasticity of not less than 15 per cent. They will be twin-screw vessels, with triple-expansion engines, supplied with steam from four Schichau boilers, at 16 atmospheres (240 pounds) working pressure of steam. They are to have two funnels, and an estimated speed of 27 knots, and to cost 472,000 roubles, without armament.

The 350-ton torpedo vessel *Som*, ordered at Laird's Works at Birkenhead, has the following dimensions: Length between perpendiculars, 213 feet; beam amidships, 21½ feet, and mean draught, 12¾ feet. The speed contracted for is 27 knots with full displace-

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ment (370 tons). The two triple-expansion engines, of 6,000 I.H.P., will be supplied with steam by four water-tube boilers of the Laird type, a novelty in the Russian Navy. The heating surface is estimated at two square feet to each unit of horse-power. The vessel is to be ready by the 4th of October of this year, and to cost £52,000. Her radius of action at 15 knots, with a coal supply of 80 tons, is estimated at 3,500 miles, and she is to have nine water-tight bulkheads, and the bow, for greater stability, is to be built with a great bulge.

The following ships, which are in process of construction at the yards named, have, by a rescript of the 21st December, 1898, been included in the Navy List and christened:

Battleships.—Pobieda, building at the Baltic Works. *Retvizan*, building at Philadelphia, at the Cramp Works. *Tsesarévich*, building at the Forges et Chantiers de la Méditerranée, La Seyne, near Toulon.

Cruisers.—Bayan, building at La Seyne, near Toulon. *Variag*, building at Cramp Works, Philadelphia. *Bogatyr*, at Vulcan Works at Stettin. *Askold*, at Germania Works at Kiel. *Novik*, at the Schichau Works at Elbing.

Data of the New Russian Warships.—The "Kronstadtski Vestnik" gives the following particulars of some of the new Russian warships recently ordered by the Tsar to be named and placed on the Russian Navy List: *Novik*, cruiser—builder, Schichau, of Elbing; length between perpendiculars, 347 feet 10 inches; greatest beam, 40 feet; speed, not less than 25 knots; coal consumption, 1¼ kilogrammes per indicated horse-power; engines, triple-expansion; 12 boilers, Schichau system, and three funnels; armor to extend 1.3 meters below the water line, thickness where sloping, 50 millimeters, where perpendicular, 30 millimemeters; cost without armament, 2,870,000 roubles; to be completed September, 1900. *Askold* and *Bogatyr*, cruisers—speed, 23 knots; to be completed respectively July and August, 1900. *Tsarevitch*, battleship—to be built at the Forges et Chantiers de la Méditerranée; length between perpendiculars, 388 feet 9 inches; greatest beam, 75 feet 5½ inches; depth in hold, 47 feet 10$\frac{13}{16}$ inches; draught on even keel, 26 feet; displacement, 12,900

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tons; engines, two triple-expansion, of 16,300 indicated horse-power; boilers, Belleville; normal coal supply, 800 tons, maximum, 1,350 tons; greatest distance without replenishing bunkers, 5,500 miles at ten knots with total indicated horse-power of 2,500, using 0.8 kilogramme of coal per indicated horse-power; maximum speed, not less than 18 knots, using 1.5 kilogrammes per indicated horse-power; armament, four 12-inch guns, two in each turret fore and aft; twelve 6-inch guns, two in each side turret; twenty 7.5 centimeter guns in the battery and on the upper deck; twenty-eight small quick-firing guns; four torpedo apparatus above water; electricity will be used to turn the turrets and for steering gear, etc.; there will be six searchlights and 1,200 glow lamps; cost, including armament, 30,280,000 francs, or about £1,200,000 sterling.

Retvisan, battleship—builder, Cramp, of Philadelphia; length between perpendiculars, 368 feet; greatest beam, 72 feet 2½ inches; draught, not more than 26 feet; displacement, 12,700 tons; normal coal supply, 1,016 tons, maximum, 2,000 tons; engines, two triple-expansion, driving twin-screws; maximum speed not less than 18 knots, using 2 pounds of coal per indicated horse-power; greatest distance at this rate, 3,000 miles; greatest distance at 10 knots, using 1.7 pounds of coal per indicated horse-power, 8,350 miles; armament, four 12-inch guns, twelve 6-inch guns, twenty 7.5-centimeter guns, 28 quick-firing guns, five torpedo tubes under water and one torpedo apparatus above water; armor belt, 6 inches and 9 inches, round the turrets, 10 inches. She will be similar in design to the United States battleship *Iowa*, and is to be completed within thirty months from the receipt of the order. *Pobieda* (*Victory*) battleship—displacement, 11,362 tons; length at the load line, 425 feet; extreme beam, 71 feet; draught on an even keel, 26 feet. She is a sister ship to the *Oslabia* and the *Peresviet*, and took the place on the stocks at St. Petersburg vacated by the latter. She will not stand so high out of the water as the two other vessels, and there will be one or two other minor differences. This is the third ship of the name which has appeared in the Russian Navy; the second assisted the English squadron to blockade the coast of Holland in 1798.—"Engineering."

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MERCHANT STEAMERS.

The U. S. Merchant Marine.—We have now employed in our foreign trade 294,064 tons of steamers and 443,645 tons of sailing vessels, of a value of $26,276,964 and $14,480,593 respectively, or a total of $40,757,557. In 1898 these were the vessels that carried 9.3 per cent. of our imports and exports. In 1892 Capt. William W. Bates, who had shortly before retired from the office of United States Commissioner of Navigation, published an exhaustive work on "American Marine," which is devoted almost altogether to the rise and decline of our shipping in the foreign trade. He calculates the tonnage required for the carriage of our foreign commerce in 1891, and arrives at the following:

"An estimate of our shipping necessities for the present year may be fixed at 1,200,000 tons of sail, and 3,000,000 of steam. To increase the shipping we now have in the foreign trade to this amount would require an outlay of $300,000,000. Under due protection, with this preparation made, we might command a business of $2,000,000,000, a vanishing fraction of which is now barely possible of attainment."

In that year 30 per cent. of the entries at our ports were sail vessels, while to-day only 20 per cent. is of sail. Moreover, the tonnage our foreign commerce employs has increased by one-third since 1891. It is conceded that a steam vessel is able to carry, in a year, three times as much as a sail vessel of identical size. If, therfore, we add but 100,000 tons to the sail vessel estimate to meet the increased need since Capt. Bates wrote, we shall probably concede at least all of that type, and more, that is likely to be built; and if we reduce the remaining 300,000 tons of sail to make up the one-third of increase since 1891 to 100,000 tons of steam—the equivalent of 300,000 tons of sail—and add one-third to the steam tonnage estimated by Capt. Bates, our shipping necessities to-day would be as follows:

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	Tons.
Sail vessels,	1,300,000
Steam vessels,	4,100,000
Total,	5,400,000

Deducting from the above the tonnage under our flag in the foreign trade we would require the following additional tonnage, if American ships wholly superseded all foreign ships in our foreign trade:

Sail vessels,	856,355
Steam vessels,	3,805,936
Total,	4,662,291

As a matter of fact, existing American shipyards could not construct that tonnage within twenty years, at which time our shipping necessities would probably have again doubled. But there is nothing, except the demand for ships, to prevent enormous increases in our shipbuilding facilities.

The census report of the average value of the steam and sail vessels engaged in carrying passengers and freight, above referred to as the basis for our computations and comparison, places the value of our steam vessels on the Atlantic and Gulf at a fraction less than $76 per ton and sail vessels in that trade at a fraction under $31 a ton. The values on the Pacific coast are much higher, but these we exclude from our comparisons in order to be conservative. We also have assumed for comparison purposes, and to be fair, that there has been a reduction of about 12 per cent. in the cost of vessels, wherefore we place the probable cost of new steam tonnage at $67 and of sail at $27 per ton. To supply the additional tonnage that would be necessary to carry all of our foreign commerce under our own flag would involve the following expenditures in American shipyards:

856,355 tons of sail vessels at $27 per ton,	$22,121,585
3,805,936 tons of steam vessels at $67 per ton,	254,997,712
4,662,291 tons of sail and steam vessels,	$277,119,307

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American labor would, from the mine and forest to the finished ship and through all the processes to which the raw material would be subjected, receive about 95 per cent. of that vast sum, if the ships our foreign commerce employs were built in the United States. But that sum we are now paying to foreign ship-owners who, in turn, expend it in the employment of aliens in foreign shipyards and on board foreign ships.—"Marine Record."

S. S. Nantucket.—This steamer was launched March 16, at the works of the Harlan & Hollingsworth Co. She was built for the Merchants' and Miners' Transportation Co., of Baltimore, being the eleventh vessel built for this company. The *Nantucket* is 294 feet long, 42 feet beam, and 34 feet depth of hold. Engine, triple compound with inverted cylinders, 28 inches diameter; intermediate, 45 inches; low-pressure, 75 inches; stroke, 54 inches. Four cylindrical and return-tubular boilers, diameter of shell, 14½ feet; length inside, 12 feet; three furnaces in each leading to separate combustion chambers; diameter of furnaces, about 50 inches outside; grate surface, about 320 square feet; heating surface, about 1,160 square feet; pressure, 170 pounds per square inch. The vessel is a four-decked ship with two cargo ports; two coal ports on each side in second between decks, and three cargo ports and one air port opposite the kitchen on each side on the third between decks. On the third deck there is a passenger saloon with twenty state rooms, pantry and toilet, fitted with light hardwood, and having large open double stairway. The main saloon is about 72 feet long and 30 feet wide. The kitchen and second-class rooms, cook's and wash rooms are on third deck. On this deck there is also a forecastle with proper accommodations for stores, ice, oil, lamp rooms, etc. On the spar deck abaft smoke stack there is a house containing engine-room opening, engineer's room, social hall, toilet rooms, passengers' state-rooms, etc. Surrounding the smoke stack is a house containing smoking rooms, toilet and officers' rooms, etc. Forward of smoke stack will be a house containing ten state-rooms for passengers. On top of this house is a pilot house. The vessel is schooner rigged, with two pole masts with wire standing rigging. All staterooms are finished in hard wood.

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The Lake Freight Steamer "Troy."—Within recent years there has been a marked increase in size and an improvement in the construction of the steamers on the Great Lakes, not only for those employed in the coal and ore traffic, but also those for general freight traffic. A good example of the modern lake freight steamer is the *Troy*, which was built in 1898 for the Western Transit Co., of Buffalo, N. Y., operating what is known as the New York Central and Hudson River R. R. Lake Line. The steamer runs regularly between Buffalo and Duluth. Many of our readers who attended the convention of the American Society of Civil Engineers at Detroit, last summer, will remember seeing the hull of the vessel at the Wyandotte shipyards, and the engines at the Detroit engine shops. The ship and its engines were built by the Detroit Dry-Dock Co., of Detroit, Mich. The general dimensions are as follows:

Length on keel, feet and inches	380–6
Length over all, feet and inches	402–6
Beam, molded, feet and inches	45–6
Depth, molded, feet and inches	28–0
Height between decks, molded, feet and inches	9–3
Mean draught, feet and and inches	17–6
Cargo capacity on net draught, net tons	5,100
Engine cylinders, diameters, inches	19, 27½, 40 and 58
Engine cylinders, stroke, inches	42
Boilers (3 Scotch marine), diameter, feet and inches	11–0
Boilers, length, feet and inches	11–6
Boilers, pressure, pounds	210
Total heating surface, square feet	4,617.6
Total grate surface, square feet	102.4
Ratio heating surface to grate surface	45 to 1.04

The steamer is designed for both package and coarse freight. The hull is of steel, with framing of channel construction, and the cargo hold is divided into five compartments by screen bulkheads. It is double-decked for the entire length, and has a topgallant forecastle, an orlop deck forward and aft, and water ballast in ten compartments 5 feet deep, of about 2,000 tons capacity. There are eleven hatches on each deck, and seven water-tight gangways between decks. The decks and deck houses are of steel, the latter being elaborately finished inside with hardwood.

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A line of hoisting shaft runs from the collision bulkhead at the bow to the bulkhead forward of the boiler room. This has two hoisting drums at each hatch, and a single drum at each of the two forward gangways, the latter being used for skidding freight up the gang planks, on account of the height due to the sheer of the hull. The vessel is equipped with all the latest appliances for handling all kinds of freight, both package and bulk. It is also fitted with electric lights throughout, electric signal lights and a search light. The rig consists of two steel pole masts, the foremast being fitted with a "crow's nest" for the lookout. Two stockless anchors are placed at the bow, and a third is at the stern, the latter arrangement being peculiar to lake steamers.

The engine and boilers are placed at the extreme afterpart of the vessel. The engine is of the four-cylinder, four-crank, quadruple-expansion type, having cylinders 19, 27½, 40 and 58 inches diameter and 42 inches stroke. The high-pressure cylinder is placed forward and the first intermediate cylinder aft. The larger cylinders, with their heavier reciprocating parts, are in the middle, for the sake of a better balancing effect. The high-pressure and first intermediate cylinders are fitted with piston valves, while the second intermediate and low-pressure cylinders have double-ported slide valves, all operated by means of the ordinary link-motion and each being independently adjustable. The steam chests of the two latter cylinders are placed at the side, so as to reduce the length of the engine, the valves being worked by rocker arms. The framing consists of four columns on the back side (supporting the slipper guides), and five at the front, thus making the engine very open and accessible.

The main shaft is supported in five journals and is 12¼ inches diameter, with crank pins 12¼ inches diameter and 10 inches long. The outboard shaft is 12½ inches diameter. The propeller is of the sectional type, 14 feet diameter and 16 feet pitch. The air pump is 33 by 14 inches, with a trunk 18 inches diameter and the two feed pumps have cylinders 4 by 12½ inches. The air pump, feed, bilge and cooler pumps are all worked from the crosshead of the low-pressure cylinder by means of a lever and connections.

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The auxiliary machinery includes one duplex feed pump, 9 × 5 × 10 inches; one duplex fire pump, 10 × 6 × 10 inches, and two duplex ballast pumps, 10 × 16 × 12 inches. A double vertical engine, with cylinder 12 × 12 inches, drives the hoisting shaft, and there are two steam winches on the upper deck, two steam windlasses, and two steam capstans, one forward and one aft. The steam steering engine is of the Detroit Dry-Dock Co.'s make, and has two cylinders, 7 × 7 inches. The two dynamos are driven by direct-connected engines.

There are three Scotch marine boilers, 11 feet diameter and and 11 feet 6 inches long, built for a working pressure of 210 pounds. Each boiler has two corrugated furnaces, 39 inches inside diameter, and 226 tubes, 2¾ inches outside diameter. The total heating surface is 4,617 square feet, and the total grate area 102.375 feet, giving a ratio of about 45 to 1.04. Forced draft on the Howden hot-draft system is supplied to the furnaces by a fan 66 inches diameter and 34 inches wide, the air heater having a heating surface of 1,360 square feet. The uptakes lead to a single smokestack, 7 feet in diameter.

The contract required that the ship should carry a cargo of 5,050 net tons on a mean draught of 17 feet 6 inches, with a coal consumption per hour of 2,650 pounds, and at a speed of 13 miles per hour. On the first trial trip the results given below were obtained. This trial was made under the supervision of Mr. Hugh Wilson, Chief Engineer of the Western Transit Co., who reported that the engines worked very smoothly and without any tendency to cause vibration of the ship.

Load, net tons	5,075
Draught, mean, feet and inches	17–6
Speed, per hour, miles	13.16
Coal consumption, per hour, pounds	2,541
Coal consumption, per horse-power per hour, pounds	1.5
Horse-power of engine	1,691

For information respecting this vessel we are indebted to the Detroit Dry-Dock Co., of Detroit, Mich., and to Mr. G. L. Douglas, Vice-President and General Manager of the Western Transit Co., of Buffalo, N. Y. Mr. Douglas also informs us that his

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company has placed an order with the Union Dry-Dock Co., of Buffalo, N. Y., for a steamer of the same length and depth as the *Troy*, but with 4½ feet more beam, and some minor changes. This vessel is expected to have a cargo capacity of 700 tons more than the *Troy*.—"Engineering."

S. S. Craigleith.—On February 16 the large steel screw-steamer *Craigleith* was taken to sea for her trial trip. She has been built by Messrs. W. Gray and Co., Limited, West Hartlepool, and is the latest addition to the Craig line of steamers (Messrs. Russell and Huskie, of Leith). She takes Lloyd's highest class and is of the following dimensions: Length over all, 341 feet; breadth, 47 feet; depth, 27 feet 4 inches. Her deck erections consist of poop, long bridge and forecastle. The saloon, state rooms, captain's, officers' and engineers' accommodation is in large deck houses on the bridge and the crew's berths are in the forecastle. This hull is built with deep frames, large hatchways are fitted, six steam winches, steam steering gear amidships and hand-screw gear aft, patent direct steam windlass, patent donkey boiler, cellular double bottom for water ballast, shifting boards throughout, stockless anchors, telescopic masts with fore-and-aft rig, boats on beam overhead and all requirements for a first-class cargo steamer.

Triple expansion engines have been supplied by the Central Marine Engine Works of Messrs. W. Gray & Co., Limited, having cylinders 25 inches, 40 inches and 65 inches in diameter, with a piston stroke of 42 inches, steam being generated in the large steel boilers working at a pressure of 160 pounds per square inch. The vessel and her machinery have been completed under the personal supervision of Mr. Huskie, and this gentleman, together with Captain Murrell and Mr. W. C. Borroman (the two latter gentlemen representing the ship yard and engine works respectively) were on board to witness the trial. Everything in the engine room went exceedingly well, and to the entire satisfaction of those on board, there being no water applied to the bearings whatever, and the engines running so smoothly as not to be heard on deck; the boilers kept up an ample head of steam, and remained perfectly tight. On the conclusion of the trial the

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Craigleith at once proceeded to Cardiff, her loading port, whence she proceeds to Colombo.—"Engineering."

S. S. Claudius.—On April 20 the fine, large screw steamer *Claudius*, built by Messrs. William Gray and Co., Limited, West Hartlepool, to the order of Mr. C. Anderson, of Hamburg, was taken to sea for her trial trip. Her dimensions are: Length over all, 350 feet; breadth, 51 feet; depth, 27 feet; deadweight capacity, 6,200 tons. The cellular double bottom extends throughout the ship, and with the after-peak tank will contain 1,000 tons of water ballast, while the side tank will hold 700 tons more. The *Claudius*, in regard to ballast arrangements, is of the new type inaugurated some months ago at the yard of Messrs. William Gray and Co., on the initiative of Mr. McGlashan, their chief draughtsman. Briefly stated, the ballast tanks, in addition to the double bottom and after-peak tanks, are situated on the side of the vessel. The side tanks give sufficient immersion in water to make the vessel manageable when in ballast without straining the propeller shaft. The reports received from the *Mancunia*, a vessel previously fitted, have been eminently satisfactory as regards this new departure. Racing of the machinery has been reduced to a minimum, it is not necessary to stand continuously by the throttle valve, and there is an absence of that hammering by the sea in the fore end of the vessel which is usual in such circumstances.

The side tanks extend through the main and after holds and engine room for a length of 191 feet, in way of which the ship has double sides, adding greatly to her strength and safety. These advantages are secured without extra material being required in the construction of the side tanks. The lower decks and other parts used in strengthening ordinary ships, and which greatly impede stowage, are dispensed with, and the material is applied in building the side tanks. Hence the new type loses nothing as a cargo carrier. The engines have been supplied by the Central Marine Engine Works of the firm, and have cylinders 25½ inches, 40½ inches and 67 inches in diameter by 45 inches stroke. The boilers are three in number, 13 feet 3 inches in diameter by 10 feet 6 inches long, and work at a pressure of 170 pounds per square inch. Manganese-bronze blades are fitted, a

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Mudd's evaporator, etc., and the vessel is lighted throughout with electricity. The vessel and her machinery were put under the usual tests, with very satisfactory results, there being no hitch whatever. The average speed recorded was 11¾ knots.—"Engineering."

S. S. Montfort.—There was launched on the 13th inst. from the Jarrow yard of Messrs. Palmer's Shipbuilding and Iron Company, Limited, a steel twin-screw steamer of the following dimensions: Length between perpendiculars, 445 feet; breadth, extreme, 52 feet; depth molded, 30 feet 10 inches. She is of the three-decked type, with two steel decks laid all fore and aft, and has an iron shelter deck specially strengthened for the Atlantic trade, extending over the whole length, and above this is a shade deck covering the machinery openings. All the available space under the shelter deck and along each side under the shade deck is fitted throughout for carrying cattle. Water ballast is arranged to be carried in a deep cargo tank and in the after peak, giving the vessel a total water-ballast capacity of over 2,000 tons. She is designed to carry about 8,000 tons deadweight on a mean draught of 25 feet. The vessel is divided into eight water-tight compartments by means of seven steel bulkheads, all of which extend to the upper deck. Each cargo compartment is fitted with a complete set of grain division boards and extra large cowl ventilators. Aft of the engine room the 'tween decks are insulated and fitted with the necessary refrigerating plant for carrying about 500 tons of cargo. The engines, which are twin-screw, are also being constructed by the Palmer Company. They are of the inverted triple-expansion type, each set having cylinders 26 inches, 43 inches and 70 inches in diameter by 45-inch stroke, steam being supplied by three double-ended boilers, 14 feet 6 inches in diameter by 17 feet 6 inches long, with a working pressure of 180 pounds.—"Engineering."

S. S. Castilian.—The new Allan Line steamer *Castilian*, built by Messrs. Workman, Clark & Co., Belfast, ran her official trials on February 9th, on the Firth of Clyde. The *Castilian* is the first of three new passenger steamers now building for the Allan Line service between Liverpool and Canada. These steamers

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are specially designed to meet the modern requirements of the Canadian trade. They are to combine with high speed great cargo-carrying capacity and the highest class of passenger accommodation. The principal dimensions of the *Castilian* are: Length, 470 feet; breadth, 53 feet 9 inches; and depth molded, 36 feet. There are three complete steel decks, extending all fore and aft, and over the upper deck a permanent shelter deck is built with bridge above. Part of the lower 'tween decks is insulated to form refrigerating chambers for the carriage of perishable goods, and a chamber is specially set apart for consumable stores for the passengers' use during the voyage. The first-class passengers' accommodation is placed in the bridge house amidships, which is entirely fitted for their use. The dining saloon, to seat 100 passengers, is at the forward end and across the vessel, and the staterooms are arranged on each side of the ship abaft this. A number of rooms are fitted with two berths. The music room is over the dining saloon, and is very handsomely finished and upholstered, and is reached by a staircase from the dining saloon. A commodious smoke room is fitted up at the after end of the bridge. Adjacent to this is a barber's shop and bar. The second-class passengers are located on the main deck, and the dining saloon is capable of dining 150 persons together. The steerage passengers are berthed on the main deck forward, and are accommodated in staterooms containing four to six berths each. As a result of several runs over the measured mile, the vessel obtained a speed of about 15½ knots, which was regarded as satisfactory.—"Engineering."

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YACHTS.

The New Steam Yacht Willada.—Col. Wm. Hester, the managing owner of the "Brooklyn Daily Eagle," has decided to practically identify himself with steam yachtsmen. For years he has been an ardent devotee to the sport of yachting, but heretofore his tastes have run toward the sailing craft. The news of his new venture in yachting will be welcome to all classes of yachtsmen, as the Colonel is a favorite among the fraternity. He is a member of the New York, Atlantic, Larchmont and Shelter Island Yacht Clubs, and he will probably make the New York Club the home anchorage of his new yacht and fly the New York flag. It has been decided to christen the new yacht the *Willada*, and she will be launched early in the spring and go into commission in the early summer. The *Willada* is from the board of the well known naval architect, H. C. Wintringham, and is now being constructed at the yard of the Pusey & Jones Co., Wilmington, Del. Her dimensions will be 128 feet over all, 102 feet on the water line, 16 feet 7 inches beam; depth of hold, 9 feet 9 inches; draught, 6 feet, leaving a freeboard amidship of nearly 4 feet.

The hull is built of steel and is of a very shapely model. She has a long, graceful overhang aft, and the forward overhang is enough for grace without being abnormal, as too many are nowadays. Her lines are finely drawn, with a sharp entry, the greatest beam being just abaft the foremast. Her sheer, while slight, is enough for beauty and to save wet decks. Altogether she is a very graceful craft, and presents a wholesome contrast to many of the modern steam yachts in which strength and stability are sacrificed in the attempt to obtain extreme lightness. A careful distribution of the material used and the choice of that which possesses the maximum of tensile strength with the minimum of weight have made her one of the strongest and stanchest of her

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class which will be afloat next summer, with a total of but 10 per cent. more strength than is called for by the rules of the Marine Insurance Association.

The *Willada* will be schooner rigged, with just enough rake to the masts to correspond with her sheer and give her a yachty appearance. Her spars, however, will be substantial and worthy of trust in an emergency. Her figurehead will be an eagle's head with scroll neck extending into the hawse hole. Provision is made for an awning, running from the forestay to the stern, which in the warmest weather will make the whole craft cool and comfortable as well for the crew as for the owner. The deck fittings will be of teak and mahogany, embellished with just enough brass to make a neat finish. There will be two deck houses, the larger being forward of the smoke stack, the foremast coming up nearly through the center of it. The forward house will be the dining room. The after house, just abaft the mainmast, will be a saloon, with a table and seats, and a stairway leading down to the owner's apartments. The galley will be below the forward house, and will be fitted with an elevator, in a vertical shaft, connecting with the pantry above, as well as every modern convenience for a modern culinary department. The officers' staterooms and messroom will be just forward of the galley. Forward of these will be the forecastle and crew's quarters. The boiler and engine room will occupy the space aft of the galley.

The owner's apartments, consisting of five rooms, reached by staircase from the after deck house, will be in the after part of the vessel. There will be two large staterooms, with a door connecting, so that in case of necessity they can be thrown open en suite. There will be a bath room, with every modern convenience. Next aft is to be a main saloon, arranged with two sofas, which can be transformed into two very comfortable berths. Beyond this and abreast of the stairway there will be a single stateroom, a toilet room and a large linen closet, while aft of all will be a double stateroom, the whole width of the vessel, with two berths, two sofas and ample lockers. All the rooms will be lighted by skylights overhead and ports in the side of the yacht,

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the matter of lighting and ventilation having received special care and study. The yacht will be lighted throughout by electricity and arrangements have been made so that steam heat can be easily and quickly installed for use in the fall and spring.

The boiler will be of the Almy water-tube type of ample size, and the engine a triple-expansion, built by the Fore River Engine Co., of Weymouth, Mass., with cylinders 9, 14¼ and 23½ inches in diameter, with a common stroke of 14 inches. The wheel will be of bronze, and all the fittings of the best quality and finish. The yacht will carry an 18-foot naphtha launch and two other boats. Her speed, it is estimated, will be between 15 and 16 miles an hour under forced draft.—"American Shipbuilder."

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OBITUARY.

ROBERT ROSE LEITCH.

Chief Engineer Robert Rose Leitch, U. S. Navy, died at the Naval Hospital, Brooklyn, N. Y., on the 14th of March last, after an illness of but four days.

The illness from which Chief Engineer Leitch died was that dreaded infliction, appendicitis.

This officer was born February 6th, 1850, and was consequently a trifle over forty-nine years old. He entered the Naval Academy as Cadet Engineer, October 1st, 1871, and from the first took the leading place in his class, graduating at the head of his date May 31, 1873. His promotions followed in due course, and his commission as Second Assistant Engineer was of the date of January 23, 1874, Passed Assistant Engineer 15th of January, 1879, and Chief Engineer September 30, 1894.

Chief Engineer Leitch was placed on the Retired List for disability in the line of duty on the 19th of February, 1896.

The sea service of this valuable officer was world-wide, and in the course of his service on the China Station, was wrecked on the U. S. S. *Ashuelot* off the ancient town of Swatow, on the 18th of February, 1883, on which occasion eleven of the ill-fated craft were drowned.

At the beginning of the Spanish war, Chief Engineer Leitch promptly requested transfer to the active list, and was assigned to duty at the Navy Yard, Pensacola, Fla., where he remained until the need for his services was over, and then returned to Brooklyn, where, as stated above, he died as the result of an operation for appendicitis.

He leaves a widow, but no children. The interment was in Baltimore.

Chief Engineer Leitch was of exceptional ability in his profession, and was held in high esteem by all with whom he ever came into official contact.

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JOHN LOUIS LAY.

The subject of this notice was born in 1835, in the State of New York, and was appointed a Second Assistant Engineer in the United States Navy from Iowa July 8, 1861. July 19, 1861, he was assigned to the screw steamer *Louisiana* of the North Atlantic Blockading Squadron, of which vessel he was the senior or chief engineer, and where he soon became prominent for general usefulness. In February, 1862, the *Louisiana* formed part of an expedition commanded by Lieutenant Wm. N. Jeffers, U. S. Navy, sent to seize and obstruct the Albemarle Sound end of the Chesapeake and Albemarle Canal. Mr. Lay, with a force of mechanics from the different vessels, covered by a picket-line of sailors, was charged with the work of obstruction, and performed it so thoroughly, by sinking schooners and a large dredging machine in the mouth of the canal, that he was specially commended to the Department by the officer commanding the expedition. A year later, in April, 1863, he was again highly commended by Commander Renshaw, of the *Louisiana*, and by Rear-Admiral S. P. Lee, commanding the squadron, for conspicuous service rendered during the investment of Washington, North Carolina, by the enemy. Owing to lack of other officers, Mr. Lay volunteered for and was put in charge of the battery of an armed transport, the *Eagle*, which for eighteen days was almost constantly engaged with shore batteries and riflemen making an unsuccessful attempt to drive the Federal vessels away and gain possession of the town.

In september, 1863, he was ordered to examination for promotion, and was advanced to the grade of First Assistant Engineer to date from October 15, 1863. While attached to the *Louisiana* he had exhibited great ingenuity in improvising torpedoes, which was reported to the Department and led to his being ordered, in December, 1863, to duty in New York, where he was given the means and opportunity to perfect his plans and conduct experiments. While there he became associated with Chief Engineer Wm. W. W. Wood, U. S. Navy. The repeated success of the Confederates with torpedoes caused the Navy Department, early

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in 1864, to issue proposals inviting inventors to submit plans for these weapons of warfare and methods of using them. From the many projects submitted those of Wood and Lay were accepted, and those engineers immediately began constructing boats and torpedoes according to their proposals. They used a steamer, similar to the standard Navy steam launch, carrying, on a long spar projecting from the bow, a canister containing about forty pounds of gunpowder. Effective though somewhat complicated mechanism was provided for detaching the torpedo and exploding it. Several of these outfits were provided during the summer of 1864, and it was with one of them that Lieutenant Cushing destroyed the *Albemarle* in October of that year.

Besides designing these small boats and torpedoes, Messrs. Wood and Lay proposed a genuine torpedo boat, to be armored and to carry a torpedo on a spar or boom large enough to require steam power to run it out and in from the bow of the vessel. A boat on their plan, named *Stromboli* and later *Spuyten Duyvil*, was immediately built at a cost of about $45,000. It was 84 feet long; 21 feet beam; about 8 feet draught; 207 tons displacement, and had 5 inches of armor on the sides and 3 inches on deck. A full description of this first torpedo boat of the United States Navy is given in "Barnes' Submarine Warfare," and in a pamphlet on spar torpedoes by Lieutenant-Commander R. B. Bradford, U. S. Navy. October 4, 1864, Mr. Lay was detached from duty in connection with the building of the *Stromboli* and ordered to command that vessel, his orders reading as follows:

"SIR: You are hereby detached from special duty at New York, and you will report to Rear Admiral Gregory for the command of the torpedo-boat *Stromboli*.

"Very respectfully,

"GIDEON WELLES.

"FIRST ASS'T ENG'R J. L. LAY,

"New York."

As Mr. Lay was a staff officer, and not in the line of command, this order was a high compliment to his ability and knowledge as recognized by the Navy Department. Under his command the *Stromboli* was employed for several months during the latter

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part of the war in the James River, and performed valuable service there by blowing up obstructions to navigation that had been placed in the river by both Union and Confederate combatants.

In May, 1865, the war being over, Mr. Lay resigned from the Navy and was soon heard of in Peru, by which country he was employed to place torpedoes in its harbors as a defense against a threatening Spanish squadron. At Callao, in 1866, while planting an electric-defense torpedo with wire attached, he conceived the idea of a dirigible torpedo to be controlled by electric currents. With this idea he returned to the United States, and in 1870 completed the first movable torpedo that was known by his name. This was about 25 feet long, with fusiform body, about 30 inches in diameter at the largest part, and contained many of the essential features of torpedoes now in use. It was driven by a screw propeller, actuated by an engine, the motive power of which was carbonic acid gas obtained by releasing liquid carbonic acid from a containing vessel within the hull of the torpedo. A smaller gas engine worked the rudder, and was itself controlled by electro magnets under the influence of a current sent over a wire paid out from the torpedo as it advanced. This torpedo was sold to the Egyptian Government.

The second dirigible Lay torpedo, completed in 1872, was somewhat larger than the one just described, and had certain improvements, an important one being electrical control of the propelling engines that enabled them to be started or stopped at will. This was sold to the U. S. Navy Department for experimental use at the torpedo station at Newport. Its mechanism is fully described by Lieutenant-Commander Bradford in one of the torpedo-station pamphlets before referred to.

The third torpedo made was sold to Egypt and the fourth to the United States. Important improvements possessed by them were horizontal fins or rudders, electrically controlled, by which they could be made to dive or rise, and the feature of the dropping magazine. The latter was a provision by which the explosive charge, normally a symmetrical part of the body of the torpedo, was detached on impact and allowed to sink to a depth

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regulated by an attached chain. Experiment had shown that more damage was done by submerged explosion than resulted when the magazine or explosive was detonated when attached to the body of the torpedo at the surface. Following these, eleven torpedoes were sold to Russia in 1879 for $250,000, and the same year ten others were sold to Peru, then at war with Chile.

It is unnecessary for the purposes of this notice to follow the development of the Lay torpedo from the beginning that has been outlined. Modern torpedoes, by virtue of superior and more accurate processes of manufacture and by having the advantage of numerous recent inventions, are improvements, but their essential features are still only amplifications of Mr. Lay's ideas. For his own labors he was well rewarded, as he received at least one million dollars from the sale of torpedoes or the right to manufacture them. Like many other rare geniuses, he is said to have had no orderly business methods and no idea of the value of money, spending great sums on visionary experiments in the most prodigal manner. For these reasons his later years were made sorrowful by poverty, and he was on occasions saved from actual want by the generosity of friends who had known him in the days of his prosperity and who appreciated the value of his contributions to the triumph of machinery that the last half of this century has seen.

He died in Bellevue Hospital, New York, of erysipelas, April 18, 1899, so unknown that his name and history were not learned by the hospital officials until after his death. He leaves a wife, who has long lived in London, a married daughter in Java, and a son on the Pacific coast. His body was sent to Buffalo, his boyhood home, for burial, and his papers relating to his share in the world's work will be delivered to the Buffalo Historical Society.

SIR JAMES WRIGHT.

Sir James Wright, C. B., late Engineer-in-Chief of the British Navy, and a vice-president of the Institution of Naval Architects, died at Norwood on April 17, 1899, in his seventy-sixth year.

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Sir James Wright, who was the son of Captain George Wright, of Lawton, Perthshire, received his engineering training at Dundee, and entered the Admiralty Service at woolwich Dockyard in 1845. He was transferred with the Steam Department of the Navy from Woolwich to Somerset House in 1847, and subsequently to Whitehall. He was appointed assistant to the Engineer-in-Chief of the Navy, Mr. T. Lloyd, in 1860, and on Mr. Lloyd's retirement in 1872 he became Engineer-in-Chief which post he held till his retirement in 1887, when he received the honor of knighthood.

The public services of Sir James Wright extend from almost the beginning of our steam navy to the year 1887, when marine engines had reached a very high state of perfection. In 1860, when he was appointed assistant to the Engineer-in-Chief, the simple engine with jet condensers, box boilers and about 20 pounds pressure, was in use. Then under his *régime* followed the successful reintroduction of the compound engine, which had been previously tried and abandoned; the adoption of twin screws; the steady rise of steam pressure to the limit of economy obtainable in practice with the compound engine; forced draft; the introduction of the triple-expansion engine, and consequent further rise of the pressure to the limit practicable with the circular boiler, and the special types of torpedo-boat machinery. Throughout the period of Sir James Wright's connection with the steam department of the Navy steam machinery was in a constant state of transition, and for the great changes therein he was more or less responsible, and his name must always be associated with them. By all those who knew him or served under him he will be remembered as a kind friend and an able chief.—"Engineering."

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BOOK REVIEWS.

THE UNITED STATES STANDARD REGISTER OF SHIPPING FOR 1899–1900 appears in form highly complimentary to both editor and printer. It now includes the classification of a large number of American steam vessels, and presents the data regarding them in the clearest type and most accessible arrangement. The construction rules for steel vessels have been thoroughly revised and made very complete. The rules and tables of scantlings are prepared in the most convenient shape for practical use. The United States Standard Steamship Owners', Builders' and Underwriters' Association, Limited, Post Building, New York City, issues this valuable book.

THE EIGHTH EDITION OF HELIOS, issued by the Heine Safety Boiler Co., is one the best arranged semi-advertising data books we have seen. The typography is excellent, and the tables and chapters of information on maters relative to power production and use are up to date and in such form as to make the volume a very desirable one for ready reference.

IN MENTIONING this class of literature, we must not fail to note the new edition of the catalogue of the B. F. Sturtevant Co., Boston, Mass., of steel-plate fans, accompaning their volume on *Ventilation and Heating*, which so many have found useful in planning for this kind of work. Those interested should request a copy of each of these books.

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ASSOCIATION NOTES.

ANNUAL DUES.—Many supporters of the JOURNAL are under the impression that annual notices are sent to all members, associates and subscribers when their dues are payable. This is not the case, as the majority of the interested are familiar with the By-Law governing this rather important duty. For the benefit, however, of those who await a notice, we would state that it is desirable to have all dues paid as soon after January 1st of each year as is convenient. In this way the rules are not only carried out, but we are assured of the intention of our members to continue their support at least during the year then beginning.

IMPORTANT BY-LAW CHANGE.—At a meeting of the Council of the American Society of Naval Engineers, held March 31, 1899, it was decided to submit to the members of the Society the following proposed change in the By-Laws, made necessary by the amalgamation of the Line and Engineer Corps of the Navy by the Personnel Bill, in order that these By-Laws may be consistent with the continuance of the Association. For Article 5, as now written, substitute the following:

"5. Officers of the Line and Construction Corps, and ex-officers of the Engineer, Line and Construction Corps of the Navy, and officers and ex-officers of the Revenue Cutter Service, shall be eligible as members."

A notice of this proposition was mailed to each voting member with a request that he would mail his approval or disapproval of the change. So far the returns have indicated an almost unanimous approval, but the final vote will be announced in the next JOURNAL. Any member not having received the notice will oblige the Council by acting upon this and forwarding his vote to the Secretary-Treasurer.

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BACK NUMBERS OF THE JOURNAL.—There have been from time to time requests for back numbers of the JOURNAL which we were anable to fill. At present, however, there are no unfilled orders of this kind; but in view of the possible desire of some of our number to either fill up a deficient set or to purchase a full set, we would state that there is on hand a fair supply of most of the back numbers. As to full sets, we have one, which we are desirous to dispose of at the highest price obtainable, for the benefit of the estate of a deceased member, an Engineer Officer of the Navy. Any offers will be promptly referred to the present owner of these volumes.

OFFICIAL TITLES.—The changes in these made by the Personnel Bill have not been adopted in addressing the present number of the JOURNAL, but will appear on all future issues.

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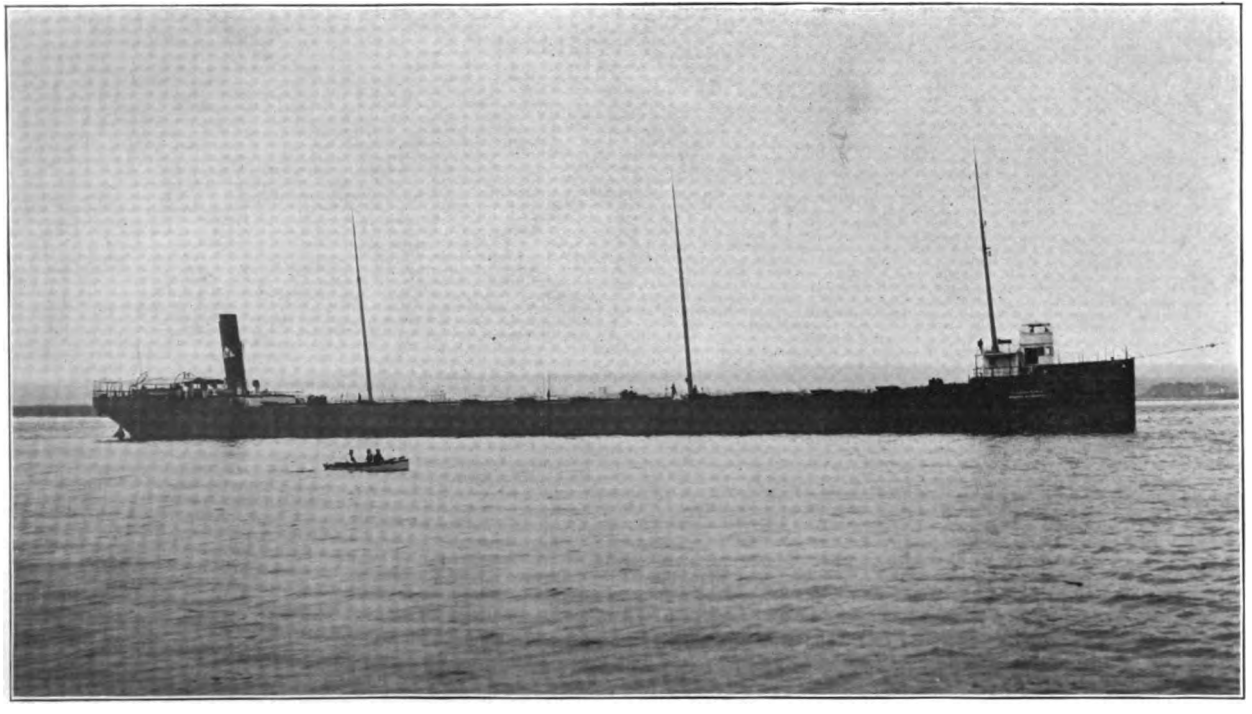

S. S. "PENNSYLVANIA."

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JOURNAL

OF THE

AMERICAN SOCIETY OF NAVAL ENGINEERS.

VOL. XI. AUGUST, 1899. No. 8.

The Society as a body is not responsible for statements made by individual members.

COUNCIL OF THE SOCIETY
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TEST OF THE MACHINERY OF THE MINNESOTA STEAMSHIP COMPANY'S STEAMER *PENNSYLVANIA*.

BY LIEUTENANTS B. C. BRYAN AND W. W. WHITE, U. S. NAVY.

When one considers the vast amount of capital invested in marine machinery and the immense pecuniary importance attaching to any improvement in design, by means of which even the smallest percentage of reduction in cost per horsepower is permanently effected, the great value of accurate data upon which to base theories for improvements and apply remedies for notable defects, is manifest.

Machinery performance data, to be of any real value, should be secured by expert engineers, and not only must the recorded observations be accurate beyond question, but must also cover such length of time under each phase of conditions as will eliminate any serious defect upon the results which an occasional abnormal datum or personal misreading might otherwise have.

Unfortunately, such accurate data are most difficult to obtain, not only owing to the attendant preparation and expense, but

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also to the interference the work creates to the ordinary services of the vessel under observation.

Of late much study has been given to improving the cylinder ratios, reducing the cost of auxiliary machinery by utilizing their exhaust to heat the feed water, and to improvements in methods of stoking; and when occasion was given to obtain general performance data of the large steamer *Pennsylvania*, incident to a test, under the directions of the Bureau of Steam Engineering, of the mechanical stokers installed thereon, every care was taken to include as many as possible bearing on these points.

GENERAL DESCRIPTION.

The vessel, which is of steel throughout, and recently put into active service, was built by the Cleveland Shipbuilding Co. for carrying freight on the Great Lakes. All hull plates are lapped and double riveted along the sides, and treble riveted at the ends; the framing is of channel bars. The upper deck alone extends the entire length of the ship, the interior of the hull being strengthened by longitudinals, beams and partial athwartship bulkheads.

The engine and boilers are placed at the extreme after end of the vessel. One athwartship coal bunker is located immediately forward of the forward boiler-room bulkhead. Quarters for the crew are in the bow, and between these and the forward coal-bunker bulkhead the space is utilized for thirteen large hatches, equally spaced, being provided for ease in loading and discharge.

The principal dimensions of the hull are as follows:

Length between perpendiculars, feet	430
Length over all	450
Beam (moulded), feet	50
Draught (deep), feet	18
Displacement, in tons of 32 cubic feet at 18 feet draught	10,155
Displacement per inch draught (at 14 feet 6 inches draught) in tons of 32 cubic feet	49
Co-efficient of displacement—block	.83
Co-efficient of displacement—midship section	.85
Ratio to rectangle—midship section	.989
L.W.L. co-efficient at 16 feet draught	.899
Double-bottom water-tight compartments	12

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ENGINE.

The main propelling engine is of the vertical, direct-acting, inverted, jet-condensing, quadruple-expansion type, designed for a maximum horsepower of about 1,600. One piston valve, actuated by a Joy valve gear, is fitted on the side for each of the high, first and second intermediate-pressure cylinders. The low-pressure valve is a double-ported slide, placed on the after side of the cylinder, and operated by eccentrics and a double-bar Stephenson link. All cylinders are unjacketed.

Cheapness in construction is a chief characteristic in the design of the main engine. The framing and bed plate are of cast iron, and all principal bearings consist of a cast-steel or cast-iron shell lined with white metal. Brass for bearings, or in fact for any purpose, is avoided wherever practicable.

The principal data of the engine are as follows:

Number of cylinders		4
Diameter of cylinders, inches	H.P.	15¾
	1st I.P.	23¾
	2d I.P.	36½
	L.P.	56
Stroke, inches		40
Diameter of piston valves, inches	H.P. (one)	12
	1st I.P. (one)	16
	2d I.P. (one)	22
Slide valve L.P. double ported, ports 60 inches long by 2¼ inches steam and 4¾ inches exhaust.		
Diameter of piston rods, inches		4¾
Length of connecting rods (between centers), feet		9
Least diameter of connecting rod, inches		5¼
Distance between cylinder centers in feet and inches	H.P. to 1st I.P.	3–8
	1st I.P. to 2d I.P.	3–8
	2d I.P. to L.P.	4–9

Order of cylinders from forward: (1) H.P., (2) 1st I.P., (3) 2d I.P., (4) L.P.

Sequence of cranks: H.P., 2d I.P., 1st I.P., L.P.

The H.P. and 1st I.P. are at 180 degrees, as are the 2d I.P. and L.P., the former being at right angles with the latter.

There is a counterbalance on after crank web to balance extra weight of L.P. piston.

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The crank shaft is 11 inches in diameter.

Crank pins, 11½ inches in diameter by 11 inches long.

Length of crank-shaft bearings (from forward), 16 inches, 16 inches, 16 inches, 22½ inches and 16 inches.

Thrust bearing, 5 horse shoes; collars on shaft, 19½ inches and 12 inches diameter, 3 inches thick, spaced 5½ inches apart; after end of thrust has line-shaft bearings 11 inches long.

The stern bearing has one lignum vitæ bearing at after end, length, 3 feet 6 inches.

Total length of shafting in vessel, 48 feet 7½ inches.

There is one vertical jet condenser.

BOILERS.

Steam is supplied by two boilers of the Babcock & Wilcox water-tube marine type, built for a pressure of 250 pounds. Each boiler is 9 feet 3 inches long, 12 feet 6 inches wide, and 16 feet 8 inches high, containing 3,000 square feet of heating surface and suitable for 65 square feet of grate surface.

Weight of boilers dry, . . .	145,860 pounds.
Weight of water contained, . .	33,492 pounds.
Total weight of boilers and water,	179,352 pounds.

Each boiler consists of eighteen sections of straight, knobbled charcoal-iron tubes placed at an inclination of 15 degrees with the horizontal, and expanded at their front and back ends into wrought-steel staggered headers. The front headers are connected at their upper ends to a steam and water drum, and at their lower ends to a blow-off connection or mud drum by tubes 4 inches in diameter expanded into bored holes.

All steam-generating tubes are 2 inches in diameter, No. 10 B.W.G. in thickness and 7 feet 3 inches long, the connecting tubes being 4 inches in diameter and No. 6 B.W.G. in thickness. The sides of the boilers are formed by 2-inch tubes inclined the same as the generating tubes, but placed one above the other and expanded into straight manifolds or corner boxes.

The furnace sides are made up of four boxes of 5½ inches square section, pressed from open-hearth steel plate ⅜ inch in

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thickness. They are placed at an inclination of 15 degrees, and connected at their ends by means of 4-inch tubes to the corner boxes. These furnace boxes avoid the use of fire-brick side walls, and are of sufficient thickness to withstand the wear and tear of the fire tools. Brick work is used only in forming the bridge walls at the rear of the grate, which wall extends to the height of the lowest row of generating tubes.

All headers and boxes are made of open-hearth steel plate, welded after forming. As the headers are staggered, the tubes are placed in groups of four, each group being covered by a forged-steel elliptical hand-hole plate, into which is welded a stud of 1 inch diameter, the plate being drawn to its seat by a forged-steel bridge and nut, and the joint made on the inside of the header against an elliptical faced seat by a thin lead gasket.

The steam and water drum of each boiler is 42 inches in diameter and 14 feet 10 inches long over the bumped heads. The shell is of open-hearth steel $\frac{19}{32}$ inch in thickness, the heads being $\frac{3}{4}$ inch in thickness. All longitudinal seams are butted and strapped, and have six rows of rivets.

STOKERS AND BLOWER.

Three mechanical underfed stokers* are fitted to each boiler. These were installed by the American Stoker Company, and each consists essentially of a central magazine, a coal hopper, a screw conveyor or worm, a wind box, cast-iron tuyeres or air blocks, and an independent steam motor for driving the conveyor shaft. The rate of feeding coal is controlled by the speed of the motor, which has a reciprocating piston working a crosshead to which is attached suitable link connections operating a rocker arm having a pawl mechanism actuating a ratchet wheel secured to the conveyor shaft.

Coal thrown into the hopper is continually fed by the conveyor or screw into the central magazine of the stoker, being gradually forced upwards, overflowing finally the tuyere blocks. Through these latter air is supplied by a blower, installed for

* A description of this stoker was printed in No. 1, Vol. XI, of the JOURNAL.

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the purpose, there being openings towards the central magazine, as well as on the opposite side. The gradual heating of the coal, in its upward course, releases the volatile gases, which are burned by air issuing from the inside of the tuyere blocks. A sort of coke is thus furnished to the dead grates at the sides of the stoker, the air for the combustion of which is supplied by openings on the outside of the tuyere blocks. No air enters from the ash pit.

At the side of each stoker is located a cleaning door. Through these the fires on the dead grates are frequently sliced, and the non-combustible, in the shape of vitrified clinker, periodically removed. These doors provide means, also, of furnishing coal to the furnaces in case of accident to the stoker motors.

The weight of each stoker complete, as fitted on the *Pennsylvania*, is about 3,500 pounds.

Air is supplied to the wind boxes by one Sturtevant blower having a central duct with branches to each stoker. The fan is 60 inches in diameter, 21 inches in width at the periphery, and driven by a two-cylinder, simple, double-acting engine, with cranks at 180; the cylinder diameters and stroke are, respectively, 5 and 4 inches. One piston valve controls the admission and emission of steam to both cylinders.

AUXILIARY MACHINERY.*

Number.	Purpose.	Make.	Type.	Diameter of cylinders. H.P.	L.P.	Water.	Stroke.	Reference letter.
1	Main air pump	Blake	Vertical, compound, simplex	7½	12	20	16	A
1	Main feed pump	Blake	Horizontal, compound, duplex, plunger	6	10	5	10	B
1	Auxiliary feed pump	Deane	Horizontal, duplex, plunger	...	8	4	10	C
1	Bilge pump	Deane	Horizontal, compound	4	7	6	10	D
1	Water-service pump	Deane	Horizontal, compound	4	7	6	10	E
2	Ballast pumps	Deane	Horizontal, compound, duplex	8	12	16	18	F
1	Deck pump (for'd)	Deane	Horizontal, duplex	...	5½	3½	6	G
2	Dynamo engines	Buffalo Forge Co.	Vertical, single-cylinder	...	6	...	6	H
1	Steering engine	Clevel'd S. B. Co.	Horizontal, 2-cylinder	...	7	...	7	I
1	Windlass engine (aft)	Clevel'd S. B. Co.	Horizontal, 2-cylinder	...	...	...	...	K
1	Capstan engine (for'd)			...	...	...	...	L
5	Deck winches	Clevel'd S. B. Co.	Horizontal, 2-cylinder	...	...	...	...	M
1	Blower engine	Sturtevant	Vertical, 2-cylinder	...	5	...	4	N
6	Stoker engines	Amer. Stoker Co.	Horizontal, 1-cylinder	...	6	...	4½	O

* All auxiliary machinery is independent of the main engine.

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OBJECT OF THE TESTS.

The tests were made primarily for the purpose of observing generally the practical adaptability and working of underfed stokers (as manufactured and installed by the American Stoker Company) to boilers of sea-going vessels, especially with a view to determining the economic results where (as was the case on the *Pennsylvania*,) an inferior grade of slack coal is used. The particular coal handled on these trials was from the Essen mine in Western Pennsylvania. It contained a large percentage of refuse, and therefore afforded an excellent opportunity of illustrating any superiority in stoking which a mechanical device would give over hand firing. A test of a sample of the coal used gave, by a Mahler bomb calorimeter, 11,790 B.T.U. per pound of dry coal.

Advantage was also taken, as previously noted, of this occasion to ascertain the relative cost of operating all steam machinery installed as an integral or necessary part of the stoker equipment, and to measure the steam consumption of the main engine under various conditions, as well as to determine the economy of several of the independent auxiliaries.

DESCRIPTION OF TESTS.

In all, eight tests of the main engine were made, of which the first five were each of six hours' duration. Those covered by tables No. 1, No. 2 and No. 5 are similar, and representative of the usual power developed under ordinary steaming conditions of the vessel. Test No. 3 was made with almost maximum H.P. cut-off; test No. 4, cutting off very nearly as short as the H.P. valve gear would permit.

Tests on table No. 6 (*a*, *b*, *c*,) of three, two and one hour duration, respectively, were undertaken with the sole aim of ascertaining the economy of the main engine when working under reduced boiler pressures. No account was kept of the coal used.

The economy of the engine, as shown by these tests, is not strictly comparable, one with another, on account of the irregular operation of the air pump, causing, as will be seen from an

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inspection of the tables, considerable variation in the vacuum obtained on the different tests. A more satisfactory comparison would have been possible had the vacuum carried been about the same at all times.

Previous to beginning the above tests the dead plates of the furnace fires were thoroughly cleaned of clinker. The same operation was repeated about an hour before each test ended, particular attention being given to have the fires, as nearly as could be judged by the eye, in the same condition at both the beginning and end. Each test was begun and finished with the stoker hoppers entirely filled; coal fired during the interval covered by the test was accurately weighed on a platform scales.

Data of the tests were collected by six observers stationed as follows: Two at main engine indicators; one weighing total feed water pumped to boilers; one weighing condensed exhaust steam from auxiliaries in operation; one collecting engine-room data; one weighing coal and noting fire-room data.

APPARATUS FOR WEIGHING FEED WATER.

During the tests, all water fed to the boilers was delivered by the air pump, through a 5-inch pipe connection to the overboard discharge of the (jet) condenser, into the upper of two tanks in the engine room, which latter were specially installed for the tests. The upper tank was mounted upon platform scales, and water flowing into it could be regulated or shut off, as desired, by means of a valve. Each tank of water, after weighing, was dropped by gravity to the lower tank, from which a suction pipe, of about eight feet in length, led to the feed pump.

Graduated wooden scales were secured between the glands of the boiler water-gage glasses, and the height of water read at the beginning and end, and at hourly periods, as the tests progressed. From an inspection of the tables, it will be observed that a correction (amounting to 192 pounds per inch of height) has been applied for differences of level in order to fix the true weight of water evaporated.

All tests began with the lower or feeding tank full and ended in the same way.

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QUALITY OF STEAM

A Barrus throttling calorimeter, attached to the main steam-pipe near the H.P. cylinder, was used to determine the quality of steam supplied by the boilers, and readings of the upper and lower thermometers are recorded in appropriate columns in Tables I–IV. After completing the tests, a calibration of the instrument in port, with fires nearly dead, and steam issuing only through the calorimeter, gave the following:

Upper Thermometer.	Lower Thermometer.	Gage on Engine.
393½	311	240
394	311	240
394	311	241
394¼	311	242
394½	311½	243
395	311½	245
395½	311½	246
396	311½	246
396	312	247
395½	311½	245
394½	311	243
393½	311	240
393	311	238
392	311	...
391	310½	...
390	310	230
389	309¾	...
388	309½	...
387	309¼	...
386	309	217

The moisture in the steam, as figured, after making due allowance for condensation in the instrument, is so infinitesimal as to be entirely negligible in the final results. The assumption has been made, therefore, that dry steam was furnished during all the tests.

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METHOD OF AND APPARATUS FOR MEASURING THE STEAM USED BY THE AUXILIARIES.

The method adopted to determine the amount of steam used by the auxiliary machinery was to condense the exhaust steam therefrom and weigh the resultant water. This condensation was accomplished by means of a cylindrical exhaust feed-water heater, of the surface-condenser type, containing thirty-eight 2-inch tubes 9 feet long. The feed water, on its path to the boilers, passed through these tubes and condensed the exhaust steam from the auxiliaries, which was directed into the shell, and at the same time elevated its own temperature proportionally. In order to reduce the temperature during the tests, the drain from the shell of the feed heater was led to a coil contained within a barrel, into which latter a stream of water from the outside ran and overflowed into the bilge. A second barrel, mounted upon platform scales, finally received, by gravity, the condensed exhaust steam of the auxiliaries. As soon as the weighing barrel was filled, the inflow was momentarily stopped, the weight taken, and then the condensed water rapidly discharged into the bilge.

The arrangement of piping was such that the feed could be by-passed around the heater if desired. A communication was also provided for atmospheric exhaust by a suitable connection and valve, fitted between the heater shell and escape pipe.

In touching upon the feed water, it may not be irrelevant to note the course of the feed water after leaving the heater. Instead of being delivered directly therefrom to the boilers, it was led to two horizontal cylindrical purifiers, one for each boiler, situated above and near the back of the latter. These purifiers contained settling pans for the removal of the impurities and scale deposits, and here the feed water was further heated by the ingress of live steam before finally entering the boilers.

STEAM CONSUMPTION OF AUXILIARIES.

On May 28th three tests were run with the view of fixing the steam consumption of the fire-room blower and air pump, and incidentally the total steam necessary to operate the several auxil-

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iary pumps and steering engine, which were in use during all the tests. The power developed by the main engine, and the average weight of coal burned, were about as shown in Table I.

An attempt was made to run the different pumps at a constant speed during the entire period covered by the tests, data being recorded at intervals of ten minutes. Only the averages for each test, however, are given in the table below.

Number of test.	Duration of test. Hours.	Boiler pressure. Gage.	Average double strokes per minute.						Temperatures.				Condensed exhaust steam.		Steam used by blower per hour.			Steam used by air pump per hour.		
			Air pump. (*A.*)	Feed pump. (*B*)	Bilge pump. (*D.*)	Water-service pump. (*E.*)	Auxiliary pump † (*C.*)	Fire-room blower. (*N.*)	Injection.	Hot well.	Feed.	Exhaust water collected.	Total.	Per hour.	By difference.	Correction.	Total.	By difference.	Correction.	Total.
		lbs.											*lbs.*	*lbs.*						
1	1½	240	*	15.2	39.4	16.3	30.6	‡	44	106.2	169	102.5	2042	1361	...	..	...	...	..	...
2	1½	237	*	14	39.7	16.9	24.7	417.4	44	102.3	188.8	98.2	2966	1977	616	62	678	...	..	...
3	1½	235	20.8	15	41.8	16.2	22.6	‡	44	104	186.5	95.9	3022	2015	...	..	...	654	67	721

* Exhausting into main condenser. † Delivering water into barrel containing cooling coil.
‡ Exhausting into atmosphere.

The air-pump piping was so arranged that the exhaust could be thrown either through the feed heater or to the main condenser. Temporary piping and valves were installed to the fire-room blower, by which means it was possible to send the exhaust, as desired, to the feed heater or atmosphere direct.

Test No. 1 shows the steam consumption of the various pumps and steering engine; test No. 2, the same as test No. 1, with the addition of the fire-room blower; test No. 3, the same as test No. 1, with the air pump added. By inspection of tests No. 2 and No. 3 it will be observed that there was a slight variation in the average speed of the different pumps as compared with test No. 1. A correction covering this has, therefore, been applied in order to arrive at the true steam consumption of the blower and air pump.

During the tests here recorded the air pump was not indicated,

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but, on May 30th, when working under almost exactly similar conditions, the average of two sets of cards gave the following:

I.H.P. of H.P. cylinder, ...	4.345
I.H.P. of L.P. cylinder, ...	4.323
Total, ...	8.668

Pounds of steam per I.H.P. per hour = 721 ÷ 8.668 = 83.18

From the results of the above tests, and a careful examination of the total and hourly condensed exhaust steam collected and weighed, the speed and auxiliary machinery in use, as shown on Tables I–IV, a close approximation to the average steam consumption per hour of each auxiliary is found to be as follows:

Auxiliary.	Reference letter.	Steam consumption per hour. Pounds.			
		Table I.	Table II.	Table III.	Table IV.
Air pump	*A*	721	715	828	613
Feed pump	*B*	487	468	595	350
Bilge pump	*D*	275	275	320	240
Water-service pump	*E*	146	154	156	150
Auxiliary pump	*C*	330	...	...	...
Starboard dynamo	*H*	...	480	480	...
Port dynamo	*H*	671	...	...	...
Steering engine	*J*	125	125	125	125
Fire-room blower	*N*	622	692	725	550
Total	...	3,377	2,909	3,229	2,028

TEST OF STOKER MOTORS.

To determine the amount of steam used in operating the stokers, the exhaust from one was (May 30, Table II,) led into a barrel containing a previously weighed quantity of water and there condensed. Two tests, similarly made, gave 22.5 and 23.7 pounds respectively, or an average of 23.1 pounds, as the hourly consumption. For all stokers the steam used per hour would, therefore, amount to 138.6 pounds.

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The cost of operating all stokers and blower, based on the results of Table II, is found to be 4.29 per cent. of the total steam generated. By reason of the blower exhaust passing through the feed heater, however, the actual net cost of the stoker installation is equivalent only to 1.68 per cent. of the steam made.

ANALYSIS OF FLUE GASES BY PORTABLE ORSAT APPARATUS.

Time.	CO_2.	O.	CO.	Remarks.
	per cent.	*per cent.*	*per cent.*	
		TABLE I. MAY 28TH.		
P. M.				
4.40	8.0	12.0	Nil.	
5.00	8.0	11.6	Nil.	
6.00	7.7	12.3	Nil.	
Averages...	7.9	12.0		
		TABLE II. MAY 30TH.		
P. M.				
4.45	8.2	11.8	Nil.	
4.55	7.5	12.3	Nil.	
5.45	7.8	11.9	Nil.	
6.00	7.3	12.1	Nil.	One minute after slicing.
6.15	8.5	11.3	Nil.	Three minutes after slicing.
6.20	7.3	12.7	Nil.	
7.55	8.0	12.0	Nil.	
8.00	6.5	13.5	Nil.	
Averages...	7.6	12.2		
		TABLE IV. MAY 31ST.		
A. M.				
10.35	5.6	14.0	Nil.	Just before slicing.
10.55	7.1	13.1	Nil.	Just after slicing.
11.10	5.2	15.2	Nil.	Doors open, taking out clinker.
11.40	7.4	11.9	Nil.	Just after slicing.
11.50	7.4	13.2	Nil.	
1.40	6.0	14.2	Nil.	
1.45	7.5	12.5	Nil.	
Averages...	6.6	13.4		
		TABLE V. JUNE 1ST.		
P. M.				
12.55	5.5	14.0	Nil.	
1.00	6.2	13.6	Nil.	
1.05	6.9	13.4	Nil.	
Averages...	6.2	13.7		

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Samples for the above tests, as well as the temperature of the escaping gases, as recorded in the tables, were taken near the base of the smoke pipe. The temperature of the gases, just after passing the dampers in the uptakes, showed, on several tests, an average of 75 degrees higher than that indicated at the base of the stack.

PRACTICAL WORKING OF STOKERS.

During the entire trip the stokers worked satisfactorily. The coal, as before stated, was a cheap grade of slack. Fires on the dead grates were sliced at about twenty-minute intervals, at which periods, also, any loose clinker was removed; each fire received a thorough clinkering and cleaning every six hours. The steam required at all times was generated without difficulty and, no doubt, with greater ease and economy than if hand firing had been employed.

Only an extremely light smoke was observable during the ordinary working of the stokers. Practically, it may be said, the coal was burned smokelessly, except when the cleaning doors were opened, either for slicing or clinkering. At such intervals considerable smoke issued from the stack.

A successful trial was made on June 2d with the stokers stopped (blower running), demonstrating the feasibility of feeding the furnaces by hand, coal being supplied through the cleaning doors.

TABLES OF TESTS.

The tables of data of the several tests referred to in this article are placed on the pages immediately following, and are themselves followed by the reproduction of the sample cards and the combined cards. This disposition is made for the greater convenience of studying the results. The general conclusions drawn from the trials tests are appended following the tables.

Variation in vacuum carried on the several trials has already been referred to. The table on opposite page shows the probable increase of power if the air pump had maintained an average vacuum of 26 inches, during the different trials, and the corresponding steam economy of the main engine under these conditions.

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S. S. *PENNSYLVANIA*.

Table showing probable results that would have been obtained on trials with same piston speed and a uniform vacuum of 26 inches.

Number of trial.	Vacuum in inches.		Additional M.E.P. in L.P. cylinder, diff. × .4	Mean revolutions per minute.	Speed of piston per minute.	Additional I.H.P. at 26 inches vac.	Average I.H.P.		Steam used in lbs. per hour by main engine. Trial.	Steam per I.H.P. per hour.			Average boiler pressure.	Cut-off in H.P. cylinder.	Ratio of expansion.
	On trial.	Difference from 26 ins.					On trial.	At 26 inches vacuum.		On trial.	At 26 inches vacuum.	Difference in lbs.			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	24.35	1.65	.660	77.33	515.53	25.30	1,206.71	1,232.01	17,252	14.30	14.00	.30	242	.644	17.95
2	23.56	2.44	.966	74.45	496.33	35.65	1,169.77	1,205.42	16,694	14.27	13.84	.43	244	.658	17.64
3	22.73	3.27	1.308	79.44	529.60	51.51	1,455.04	1,506.55	20,952	14.40	13.91	.49	241	.798	15.50
4	22.71	3.29	1.316	66.31	442.07	43.26	862.78	906.04	12,725	14.75	14.04	.71	245	.542	20.60
5	23.67	2.33	.932	73.74	491.60	34.07	1,168.88	1,202.95	16,697	14.28	13.98	.30	245	.656	17.77
6*a*	23.40	2.60	1.040	67.10	447.33	34.58	855.87	890.45	12,939	15.12	14.54	.58	197	.656	17.77
6*b*	21.60	4.40	1.760	51.02	340.13	44.51	394.94	439.45	6,815	17.26	15.51	1.75	130	.656	17.77
6*c*	21.16	4.84	1.936	44.93	299.53	43.12	264.89	308.01	5,305	20.02	17.22	2.80	108	.656	17.77

Column 4 is based on the assumption that an increase in vacuum would have produced an increase in the M.E.P. on the L.P. piston of 80 per cent. of its equivalent pressure. One inch of vacuum being .491 lb. pressure, there follows an increase of .491 × .8 = .3928 or about .4 lb. M.E.P. for every inch of vacuum.

Column 16. Ratio of the volume of the L.P. cylinder, including its clearance, to the volume of the H.P. cylinder, including its clearance, up to the point of cut-off.

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TABLE I. LOG OF TEST OF ENGINES AND BOILERS OF MINNESOTA TRANSPORTATION

Duration of test, 6 hours.

Time.	Steam pressures.					Revolutions or double strokes per minute.									Temperatures.					Dynamo.		Engine-room	
	At engines.	First receiver.	Second receiver.	Third receiver.	Vacuum.	Counter.	Main engines.	Air pump.	Feed pump.	Water-service pump.	Fire and bilge pump.	Auxiliary pump.	Fire-room blower.	Dynamo engine.	Injection.	Hot well.	Feed.	Calorimeter. Upper.	Calorimeter. Lower.	Ampères.	Volts.	Height of water in boiler water gages. Inches.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	
p. m.																						*P.*	*S.*
2·30	241	97	33	5.50	24.25	69063	...	21	14.5	19	28	34	380	...	45	103	210	392	310	...	...	4½	3
3·00	237	95	32	5.00	24 25	71410	78.0	22	15	16	51	31	390	...	45	99	206	392	310	...	...	...	
3·30	240	97	33	5.50	24.25	73746	77.9	23.5	14.5	19	29	29	382	...	45	100	211	392	310	...	...	3½	3½
4·00	240	97	33	5.50	24.25	76070	77.5	22	16	18	29	29	384	...	45	98	211	392	310	...	...	...	
4·30	240	97	33	5.50	24.25	78406	77.7	20.5	15	18	28	29	382	...	45	97	214	392	310	...	...	4½	4
5·00	236	95	32	5.50	24.50	80730	77.5	21	13	18	40	29	392	...	45	97	210	390	311	...	...	...	
5·30	236	97	33	5.50	24.50	83040	77.0	21	14	18	48	32	392	...	42	97	210	391	311	...	...	3½	4
6·00	235	94	32	5.50	24.50	85343	76.9	10	14	17	42	28	360	...	43	96	219	389	310	...	...	...	
6·30	248	97	33	5.50	24.50	87655	77.1	17	13	17	50	26	360	416	44	98	234	...	...	39.5	99.5	5	2¾
7·00	238	96	32	5.25	24.50	89990	77.8	15	15	15	50	26	400	426	44	102	239	...	...	38.5	98.5	...	
7·30	240	96	32.5	5.50	24.50	92321	77.7	11	14	14	48	27	380	422	45	102	235	...	...	38.5	97.5	4½	3¾
8·00	241	97	33	5.50	24.50	94645	77.5	11.5	16.5	14	46	26	380	418	45	103	241	...	...	37.5	96.5	...	
8·30	240	93	31	5.25	23.75	96900	75.2	6	13	15	50	23	392	424	45	102	245	...	...	37.5	97.0	4	4¼
Total.....	3112	1251	422.5	70.50	316 50	...	...	221.5	187.5	218	539	369	4974	2106	578	1291	2885	3130	2482	191.5	489	...	
Average....	239.4	96 2	32.5	5.42	24.35	...	...	17.0	14.4	16.8	41.5	28.4	382.6	421.2	44.5	99.3	222.0	391.3	310.3	38.3	97.8	...	

Throttle valve wide open during test. Cut-off as determined from cards as follows: H.P. = .644; first I.P. = .624; second I.P. = .668; L.P. = .642.

Indicator cards from the main engines were taken at half-hourly intervals, beginning at 2·30 P. M., and ending at 8 P. M.

The condition of fires under boilers at end of test was greatly different from that at beginning. An allowance has been made for this as nearly as possible, but the total weight of coal and ash for the test, as recorded in the table, is not considered altogether reliable.

The following auxiliaries were in operation during this test (for reference see table of auxiliary machinery): Air (*A*) and feed pumps (*B*); auxiliary (*C*) pump for the purpose of delivering water into the barrel containing cooling coil; bilge (*D*) and water service (*E*) pumps; fire-room blower (*N*) and steering (*J*) engine. One dynamo engine (*H*) was started at 5·48 P. M., and continued in operation until end of test. The exhaust from these auxiliaries after passing through the feed heater, was collected, and the hourly and total results are tabulated in columns 27 and 28.

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COMPANY'S STEAMER *PENNSYLVANIA*, ON LAKE SUPERIOR. MAY 28, 1899.

Draught, forward, 2 feet 2 inches; aft, 13 feet 5 inches. Speed, 13 3 miles.

data.															Fire-room data.						
Feed water.			Water from auxil's.		Mean effective pressures.				I.H.P.					Pressures.			Temperatures.		Coal data.	
As weighed. Per hour.	Corrected for height in boiler water gage: Per hour.	Corrected for height in boiler water gage: Total	Pounds per hour.	Pounds. Total.	H.P.	First I.P.	Second I.P.	L.P.	H.P.	First I.P.	Second I.P.	L.P.	Total.	Steam in boiler.	Draft in duct.	Draft in uptake.	Fire room.	Smoke pipe.	Coal. Total.	Refuse.
24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44
lbs.	*lbs.*	*lbs.*																		
...	...	...	...	...	...	...	...	...	...	...	...	...	...	246	2⅜	.32	104	450	...	...
...	...	...	...	...	107.5	47.50	18.62	7.625	315.02	324.95	304.38	294.86	1239.21	245	2¼	.32	106	440	...	...
20241	20289	20289	2738	2738	106	47.00	18.00	7.375	310.23	321.12	293.87	284.83	1210.05	240	2 7/16	.32	104	435	...	...
...	...	...	...	...	105	46.75	18.50	7.250	305.72	317.77	300 48	278.56	1202.53	245	2¾	.33	104	440	...	...
20260	19972	40261	2720	5458	108	47.50	18.70	7.365	315.27	323.70	304 51	284.10	1227 58	244	2 11/16	.30	106	440	...	...
...	...	...	...	...	106	47.00	18.80	7.080	308.64	319.47	305.35	272.03	1205 49	240	2 11/16	.31	106	460	...	...
20430	20622	60883	2730	8188	106.5	47.00	18.50	7.250	308.10	317.41	298.54	277.41	1201.46	240	2 9/16	.31	106	440	...	...
...	...	...	...	...	107	46.75	18.55	7.210	309.13	315.32	298.96	274.90	1198.31	237	2	.33	104	439	...	...
20430	20382	81265	3110	11298	103	45.50	17.88	6.630	298.35	307.67	288.91	253.42	1148.35	246	2½	.33	104	440	...	...
...	...	...	...	...	108.5	47.50	19.10	7.130	317 14	324.11	311.42	275.02	1227.69	250	2⅝	.30	106	440	...	...
20824	20680	101945	3449	14747	108	46.50	19.10	7.400	315.27	318.58	311.02	285.06	1229.93	240	2⅞	.26	104	440	...	...
...	...	...	...	...	108	45.50	18.50	7.080	314.46	309.34	300.47	272.03	1196.30	242	2⅝	.26	104	450	...	...
20446	20494	122439	3351	18098	111	47.50	18.88	7.220	313.60	313.29	297.55	269.18	1193.62	230	2⅝	.26	106	440	...	...
...	...	...	...	...	1284.5	562.00	223.13	86.615	3730.93	3812.73	3615.46	3221.40	14480.5	3145	33	3.95	1364	5754	14400	2183
...	...	...	...	...	107.04	46.85	18.59	7.22	310.91	317.73	301.29	276.78	1206.71	242	2.54	.304	104.9	442.7	...	...

Coal was fed to the boilers by six stoker (*O*) engines which exhausted into the ash pits.

Valves in the auxiliary, steam and exhaust line of piping leading to machinery forward of the boiler-room bulkhead were closed during the test, as was also the valve in the piping which makes connection between the shell of the feed heater and the escape pipe.

A very slight escape was noticed about whistle and valve. The weather became foggy, and whistle was blown at about one and one-half-minute intervals from 6·48 until end of test.

This test was made on the up-trip of the vessel without cargo, as will be observed from the draught, but with water ballast in the double bottom compartments.

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TABLE II. LOG OF TEST OF ENGINES AND BOILERS OF MINNESOTA TRANSPORTATION

Draught, forward, 17 feet 2 inches; aft, 17 feet 6 inches.

Time.	Steam pressures.					Revolutions or double strokes per minute.									Temperatures.					Dynamo.		Engine-room: Height of water in boiler water gages. Inches.
	At engines.	First receiver.	Second receiver.	Third receiver.	Vacuum.	Counter.	Main engines.	Air pump.	Feed pump.	Water-service pump.	Fire and bilge pump.	Auxiliary pump.	Fire-room blower.	Dynamo engine.	Injection.	Hot well.	Feed.	Calorimeter. Upper.	Calorimeter. Lower.	Amperes.	Volts.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
h. m.																						*P. S.*
2'00	235	94	31.5	5.00	24.25	11489	...	18	15	18	47	*	426	...	45	104	192	391	310	...	†	4½–2½
2'30	245	97	33	5.50	23.00	13732	74.8	19	16	18	44	*	434	...	45	115	204	394	312	...	†	...
3'00	243	97	33	5.50	23.50	15983	75.0	23	15	19	45	*	450	...	45	106	214	395	312	...	†	4 –5½
3'30	244	97	33	5.50	23.50	18224	74.7	24	15	18	45	*	390	...	45	108	211	392	311	...	†	...
4'00	239	96	32.5	5.25	23.50	20473	75.0	24.5	15	18	46	*	440	...	45	108	212	392	311	...	†	7 –2½
4'30	237	95	32	5.00	23.50	22695	74.1	23	15	18	30	*	441	...	44	105	206	390	311	...	†	...
5'00	240	96	32.5	5.25	23.50	24930	74.5	24	14	18	30	*	434	...	45	106	214	394	312	...	†	3½–5½
5'30	241	97	32.5	5.25	23.50	27171	74.7	24.5	17	18	39	*	442	...	45	105	212	394	311	...	†	...
6'00	223	90	30	4.75	23.75	29389	73.9	8	13	15	38	*	418	...	43	103	200	387	309	...	†	6 –6
6'30	242	97	32.5	5.25	23.50	31615	74.2	22	13	18	37	*	424	...	43	106	220	393	312	...	†	...
7'00	237	96	32.5	5.25	23.50	33861	74.9	19	15	18	35	*	420	440	44	105	224	...	...	25	†	3 –4
7'30	225	90	30	4.50	23.75	36095	74.1	20	14	18	49	*	418	452	44	100	228	...	...	36.5	†	...
8'00	244	97	33	5.50	23.50	38292	73.2	17	14	17	55	*	398	450	45	103	234	...	...	36.5	†	6½–3½
Total	3095	1239	418	6750	306.25	...	...	266	191	231	540	...	5535	1342	578	1374	2771	3922	3111	98	...	...
Average	238.1	95.3	32.15	5.19	23.56	...	...	20.46	14.7	17.8	41.5	...	425.8	447.3	44.5	105.7	213.2	392.2	311.1	32.7	...	...

* Not in operation.

† Voltmeter out of order.

Throttle valve wide open during test. Cut-off as determined from cards as follows: H.P. = .658; first I.P. = .627; second I.P. = .682; L.P. = .636.

The following auxiliaries were in operation during this test (see table of auxiliary machinery): Air (*A*) and feed pumps (*B*); bilge pump (*D*) and water service pumps (*E*); fire-room blower (*N*) and steering (*J*) engine. One dynamo engine (*H*) was started at 6'54 P. M., and continued in operation until end of test.

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COMPANY'S STEAMER *PENNSYLVANIA*, ON LAKE SUPERIOR. MAY 30, 1899.

Speed, 11.2 miles.

data.															Fire-room data.						
Feed water.			Water from auxil's.		Mean effective pressures.				I.H.P.					Pressures.			Temperatures.		Coal data.	
As weighed. Per hour.	Corrected for height in boiler water gage. Per hour.	Corrected for height in boiler water gage. Total	Pounds per hour.	Pounds. Total.	H.P.	First I.P.	Second I.P.	L.P.	H.P.	First I.P.	Second I.P.	L.P.	Total.	Steam in boiler.	Draft in duct.	Draft in uptake.	Fire room.	Smoke pipe.	Coal. Total.	Refuse.
24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44
lbs.	*lbs.*	*lbs.*																		
...	...	...	...	...	106	47.00	18.75	7.210	297.88	308.34	293.92	267.38	1167.52	241	2⅞	.33	90	425	...	...
...	...	...	...	...	108.5	47.50	19.00	7.500	305.96	311.62	297.85	278.13	1193.56	248	3¼	.32	90	430	...	...
20122	19666	19666	2360	2360	107.5	47.50	19.00	7.380	302.93	312.45	298.64	274.42	1188.44	245	3	.31	90	445	...	...
...	...	...	...	...	112	48.75	19.00	7.250	314.33	319.40	297.45	268.51	1199.69	250	2½	.28	93	420	...	...
19396	19324	38990	2436	4796	110	46.75	18.50	7.37	309.95	307.51	290.78	274.05	1182.29	248	2⅞	.32	87	410	...	...
...	...	...	...	...	110	46.75	18.50	7.250	306.23	303.83	287.30	266.34	1163.70	250	3	.33	88	410	...	...
18841	19009	57999	2442	7238	112	48.00	19.25	7.500	313.49	313.64	300.56	277.02	1204.71	247	3	.33	87	425	...	...
...	...	...	...	...	109	46.75	18.50	7.350	305.91	306.28	289.62	272.21	1174.02	245	3⅜	.32	85	425	...	...
2[illegible]300	19724	77723	24[illegible]	9735	104.5	44.50	18.00	6.875	290.13	288.42	278.77	251.88	1109.20	237	3	.31	89	410	...	...
...	...	...	...	...	107	45.75	18.50	7.375	298.28	297.73	287.68	271.30	1154.99	245	3¼	.31	88	415	...	...
18250	19010	96733	2560	12295	107	46.00	18.50	7.50	301.09	302.18	290.39	278.50	1172.16	250	3⅛	.33	88	430	...	...
...	...	...	...	...	107.5	45.50	18.50	7.000	299.27	289.21	287.29	257.16	1132.93	225	3¼	.32	80	460	...	...
19931	19403	116136	2842	15137	108.5	47.00	19.00	7.500	298.39	301.74	291.47	272.18	1163.78	243	2⅜	.32	82	430	...	...
...	...	...	...	...	1409.5	607.75	243.00	95.06	3943.84	3962.35	3791.72	3509.08	15206.99	3174	36⅞	4.13	1137	5535	14200	2575
...	...	...	...	...	108.42	46.75	18.69	7.312	303.37	304.80	291.67	269.93	1169.77	244.2	2.99	.318	87.5	425.8	...	...

Valves in auxiliary piping were arranged, and exhaust from auxiliaries in operation collected and weighed, as stated in Table I.

A very slight escape of steam was noticed about whistle and valve.

This test was made on the down-trip of the vessel with a cargo of 6200 tons (2240 pounds) of iron ore.

Condition of fires under boilers at beginning and end of test, the same, as nearly as could be observed.

Coal was fed to the boilers by six stoker (*O*) engines, which exhausted into the ash pits.

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TABLE III. LOG OF TEST OF ENGINES AND BOILERS OF MINNESOTA TRANSPORTATION

Draught, forward, 17 feet 2 inches; aft, 17 feet 6 inches.

Time.	Steam pressures.					Revolutions or double strokes per minute.									Temperatures.					Dynamo.		Engine-room: Height of water in boiler water gages. Inches.
	At engines.	First receiver.	Second receiver.	Third receiver.	Vacuum.	Counter.	Main engines.	Air pump.	Feed pump.	Water-service pump.	Fire and bilge pump.	Auxiliary pump.	Fire-room blower.	Dynamo engine.	Injection.	Hot well.	Feed.	Calorimeter. Upper.	Calorimeter. Lower.	Amperes.	Volts.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
p. m.																						*P. S*
8·00	244	97	33	5.50	23.50	38292	...	17	14	17	55	...	398	450	45	103	234	...	...	36.5	†	6½–3½
8·30	236	91	35	8.00	23.00	40626	77.8	21	18	18	57	...	440	446	44	109	219	...	...	36	†	...
9·00	232	91	34	7.50	21.00	43002	79.2	21	18	18	31	...	454	444	44	110	204	...	...	36	†	3 –3
9·30	245	94	34	7.00	23.00	45398	79.9	12	16	18	43	*	450	446	44	105	240	...	...	35	†	...
10·00	235	92	32	6.00	23.25	47782	79.5	21	16	18	48	...	460	450	44	106	210	...	...	34	†	3 –7
10·30	225	89	31	5.50	23.00	50108	77.5	22	16	19	50	...	448	450	44	104	220	...	...	34	†	...
11·00	240	95	33	5.50	23 00	52466	78.6	26	16	18	50	...	438	448	43	110	211	...	...	34	†	8½–4
11·30	245	97	35	7.00	22.75	54897	81.0	26	18	18	52	...	456	446	43	114	217	394	312	34	†	...
12·00	240	94	33	7.00	23.00	57347	81.7	25	20	18	46	...	458	446	44	112	218	395	312	36	†	3 –7½
a. m.																						
12·30	246	94	32	6.50	23 00	59780	81.1	20	17	18	48	...	464	442	43	109	218	391	311	36	†	...
1·00	230	91	31	5.50	23.00	62164	79.5	19	16	18	49	...	454	446	43	106	209	386	310	35	†	3 –5½
1·30	225	89	31	5.25	21.50	64504	78.0	20	18	18	48	...	446	448	44	110	223	394	311	34	†	...
2·00	240	91	34	6.50	22.50	66890	79.5	25	18	18	51	...	440	446	44	104	224	...	...	34	†	3½–3
Total.....	3083	1205	428	82.75	295.50	...	...	275	221	234	628	...	5806	5808	569	1402	2847	1960	1556	454.5	...	...
Average....	237.2	92.7	32.9	6.36	22.73	...	...	21.2	17	18	48.3	...	446.6	446.8	43.8	107.8	219	392	311.2	34.9	...	...

* In operation about 15 minutes between 9 and 10 P. M.

† Voltmeter out of order.

Throttle valve wide open during test. Cut-off as determined from cards as follows: H.P. = .798; first I.P. = .797: second I.P. = .802; L.P. = .746.

The following auxiliaries were in operation during this test (see table of auxiliary machinery): Air (*A*) and feed pumps (*B*); bilge pump (*D*) and water-service pumps (*E*); fire-room blower (*N*) and steering engine (*J*) and one dynamo engine (*H*).

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COMPANY'S STEAMER *PENNSYLVANIA*, ON LAKE SUPERIOR. MAY 30, 31, 1899.

Speed, 11.4 miles.

data.															Fire-room data.						
Feed water.			Water from auxil's.		Mean effective pressures.				I.H.P.					Pressures.			Temperatures.		Coal data.	
As weighed. Per hour.	Corrected for height in boiler water gage: Per hour.	Corrected for height in boiler water gage: Total	Pounds per hour.	Pounds. Total.	H.P.	First I.P.	Second I.P.	L.P.	H.P.	First I.P.	Second I.P.	L.P.	Total.	Steam in boiler.	Draft in duct.	Draft in uptake.	Fire room.	Smoke pipe.	Coal. Total.	Refuse.
24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44
lbs.	*lbs.*	*lbs.*																		
...	...	...	...	...	...	...	...	...	...	...	...	...	...	243	2⅞	.32	82	430	...	...
...	...	...	...	...	125	55.0	20.25	10.25	365.37	375.43	330.18	395.35	1466.33	237	...	.33	78	425	...	...
22831	23551	23551	3158	3158	126	57.0	20.75	10 00	374.91	395.99	344.42	392.66	1507.98	240	2¾	.33	79	460	...	...
..	...	...	...	...	128	56.5	20.25	8 90	384.24	395.99	339.09	351.75	1471.07	250	3⅛	.33	76	460	...	...
25902	25134	48685	3244	6402	121	53.0	19.50	8.25	361.41	369.61	324.89	325.17	1381.08	240	...	.34	86	450	...	...
...	...	...	...	...	121	53 5	20.00	8.25	352.31	363.70	317.45	316.98	1350.44	228	3⅛	.35	94	450	...	...
23620	23140	71825	3064	9466	129	58.0	20.25	9.00	380.94	399.89	333.57	350.71	1465.11	244	3⅛	.35	86	460	...	...
...	...	...	...	...	129	57.0	20.75	9.00	392.57	404.99	352.25	361.42	1511.23	251	3 1/16	.35	86	450	...	...
24604	24988	96813	3315	12781	129	57.0	20.00	9 [illegible]	395.95	408 49	342.44	364.54	1511.42	245	3¼	.32	93	500	...	...
...	...	...	...	...	127	55.0	20.25	8.75	386.95	391.21	344.18	351.82	1474.16	239	3⅛	.33	95	480	...	...
24860	25244	122057	3171	15952	120	55.5	19 25	8.60	358.42	387.04	320.73	338.96	1405.15	237	3¼	.33	94	480	...	...
...	...	...	...	...	128	57.5	20.25	9.00	378.70	397.19	334.21	351.38	1461.48	230	3	.33	94	520	...	...
23648	24032	146089	3161	19113	...	...	...	...	...	...	...	...	...	246	3⅛	.33	...	480	...	...
...	...	...	..	...	1383	6150	221.50	9900	4131.77	4289.53	3683.41	3900.74	16005.45	3130	33 15/16	424	1043	6045	18000	3800
...	...	...	...	...	125.7	55.9	20.13	9 [illegible]	375.62	389.96	334.85	354.61	1455.04	240 8	2.61	326	86.9	465	...	...

Bilge pump out of operation for 6 minutes, from 8·15 P. M. Fire-room blower exhausting into atmosphere (average revolutions 450) for 36 minutes, from 9·14 P. M.

Valves in auxiliary piping were arranged, exhaust from auxiliaries in operation collected and weighed, and escape of steam about whistle and valve, as noted in Table I.

This test was made on the down-trip of the vessel with a cargo of 6200 tons (2240 pounds) of iron ore.

Condition of fires under boilers at beginning and end of test, the same, as nearly as could be observed.

Coal was fed to the boilers by six stoker (*O*) engines, which exhausted into the ash pits.

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TABLE IV. LOG OF TEST OF ENGINES AND BOILERS OF MINNESOTA TRANSPORTATION

Duration of test, 6 hours. Draught, forward, 17 feet 2 inches; aft, 17 feet 6 inches.

Time.	Steam pressures.					Revolutions or double strokes per minute.									Temperatures.					Dynamo.		Engine-room: Height of water in boiler water gages. Inches.
	At engines.	First receiver.	Second receiver.	Third receiver.	Vacuum.	Counter.	Main engines.	Air pump.	Feed pump.	Water-service pump.	Fire and bilge pump.	Auxiliary pump.	Fire-room blower.	Dynamo engine.	Injection.	Hot well.	Feed.	Calorimeter. Upper.	Calorimeter. Lower.	Amperes.	Volts.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
a. m.																						*P. S.*
10·00	248	97.5	34	4.50	23.50	98700	...	19	10.5	18	25	*	340	*	42	109	222	...	...	†	†	6 –5½
10·30	242	96	33	5.00	23.[illegible]	709	67.0	17.5	11	18	40	*	334	*	43	116	220	395	311	†	†	...
11·00	243	96	33	5.00	23.00	2717	66.9	21	12	18	40	*	290	*	44	117	222	395	312	†	†	4½–6
11·30	243	96	33	4.75	22.75	4707	66.3	21.5	12	18	43	*	276	*	45	114	218	394	311	†	†	...
12·00	243	96	33	5.00	22.50	6700	66.4	19 5	12	17	38	*	340	*	44	115	225	394	311	†	†	6¾–5
p. m.																						
12·30	225	89	31	4.00	22.50	8684	66.1	22	9	18	32	*	316	*	45	115	234	386	310	†	†	...
1·00	231	91	31	4.00	23 00	10605	64.0	13	12	18	36	*	364	*	45	116	220	390	310	†	†	7 –7½
1·30	250	99	34	5.00	22 50	12573	65.6	16	11	17	32	*	376	*	45	117	232	396	311	†	†	...
2·00	244	96	33	4.75	22.50	14552	66.0	19	11.5	16	36	*	384	*	45	116	228	395	311	†	†	4½–7
2·30	241	95	33	4.75	22.50	16534	66.1	18	12	17	37	*	334	*	45	115	232	...	...	†	†	...
3·00	250	99	34	5.25	22.50	18543	67.0	20.5	12	17	36	*	354	*	45	116	234	...	...	†	†	4½–5½
3·30	244	96	34	5.25	22.50	20552	67.0	18	11	17	37	*	352	*	45	115	228	...	...	†	†	...
4·00	240	99	34	5.00	22.50	22571	67.3	18	13	18	39	*	344	*	45	118	230	...	...	†	†	5½–4½
Total	3144	1245.5	430	62.25	295 25	...	...	243	149	227	471	...	4404	...	578	1499	2945	3145	2487	...	...	...
Average...	241.8	95 8	33.1	4.79	22.71	...	...	18.7	11.5	17.5	36.2	...	338.8	...	44 5	115.3	226.5	393 1	310.9	...	...	...

* Not in operation.

† Dynamo not in use.

Throttle valve wide open during test. Cut-off as determined from cards as follows: H.P. = .542; first I.P. = .528; second I.P. = .570; L.P. = .560.

The following auxiliaries were in operation during this test (see table of auxiliary machinery): Air (*A*) and feed pumps (*B*); bilge pump (*D*) and water-service pump (*E*); fire-room blower (*N*) and steering engine (*J*).

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COMPANY'S STEAMER *PENNSYLVANIA*, ON LAKE SUPERIOR. MAY 31, 1899.

Speed, 9.8 miles.

data.															Fire-room data.						
Feed water.			Water from auxil's.		Mean effective pressures.				I.H.P.					Pressures.			Temperatures.		Coal data.	
As weighed. Per hour.	Corrected for height in boiler water gage: Per hour.	Corrected for height in boiler water gage: Total	Pounds per hour.	Pounds. Total.	H.P.	First I.P.	Second I.P.	L.P.	H.P.	First I.P.	Second I.P.	L.P.	Total.	Steam in boiler.	Draft in duct.	Draft in uptake.	Fire room.	Smoke pipe.	Coal. Total.	Refuse.
24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44
lbs.	*lbs.*	*lbs.*																		
...	...	...	...	...	...	...	...	...	...	...	...	...	...	250	1⅝	.32	...	420	...	...
...	...	...	...	...	94	37.50	17.25	5.80	236.62	220.36	242.21	192.66	891.85	247	1¾	.32	...	435	...	...
15032	15158	15158	2068	2068	91	37.50	16.50	5.75	228.72	220.03	231.34	190.72	870.81	247	1½	.32	...	420	...	...
...	...	...	...	...	92	37.50	16.25	5 80	229.16	218.05	225.81	190.65	863.67	246	1⅜	.36	82	430	...	...
15472	15166	30324	2035	4103	93	36.75	16 75	5.60	232 00	214.02	233.09	190.93	870.04	245	1⅝	.31	82	400	...	...
...	...	...	...	...	90	36 00	16.50	5.50	223.50	208.71	228.57	180.24	841.02	230	1¾	.31	76	405	...	...
14926	14380	44704	2000	6103	89	36.00	16 50	5.40	214.00	202.07	221.31	171.34	808.72	235	2½	.30	92	435	...	...
...	...	...	...	...	91	37.50	17.00	5.60	224.27	215.75	233.72	182.09	855.83	252	2¼	.34	75	450	...	...
14281	14743	59447	2099	8202	93	37.50	16.50	5.75	230.60	217.07	228.22	188.14	864.03	248	2¼	.32	76	450	...	...
...	...	...	...	...	91.5	36.00	16.75	5.70	227.23	208.61	232.03	186.79	854.66	248	2	.32	77	430	...	...
14897	15215	74662	2070	10272	94	36.00	16.75	5 75	236.61	211.54	235.19	191.00	874.34	250	2	.32	78	420	...	...
...	...	...	...	...	92	37.00	16.75	5.80	231.58	217.42	235.19	192.66	876.85	246	1⅞	.32	84	440	...	...
15066	14904	89566	2111	12383	93	37.00	16.50	5.85	235 14	218.40	232.72	195.20	881.46	245	1⅞	.32	85	440	...	...
...	...	...	...	...	1103	442.25	200.00	68.30	2749.43	2572.[illegible]	2779.40	2252.42	10353.28	3189	23⅞	418	807	5575	11800	2463
...	...	...	...	...	91.96	36.85	16.67	5.70	229.12	214.34	231.62	187.70	862.78	245 3	1.84	322	80.7	428.9	...	...

A leak around gland of one plunger of water cylinder of feed pump was detected during the test, the water from which was collected and amounted to 66 pounds per hour. Columns 25 and 26 have been corrected for this leak.

Valves in auxiliary piping were arranged, escape of steam about whistle and valve, and exhaust from auxiliaries in operation collected and weighed, as noted in Table I.

This test was made on the down-trip of the vessel with a cargo of 6200 tons (2240 pounds) of iron ore.

Condition of fires under boilers at beginning and end of test, the same, as nearly as could be observed.

Coal was fed to the boilers by six stoker (*O*) engines, which exhausted into the ash pits.

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TABLE V. LOG OF TEST OF ENGINES AND BOILERS OF MINNESOTA TRANSPORTATION

Draught, forward, 17 feet 2 inches; aft, 17 feet 6 inches.

Time.	Steam pressures.					Revolutions or double strokes per minute.									Temperatures.					Dynamo.		Engine-room Height of water in boiler water gages. Inches.
	At engines.	First receiver.	Second receiver.	Third receiver.	Vacuum.	Counter.	Main engines.	Air pump.	Feed pump.	Water-service pump.	Fire and bilge pump.	Auxiliary pump.	Fire-room blower.	Dynamo engine.	Injection.	Hot well.	Feed.	Calorimeter. Upper.	Calorimeter. Lower.	Amperes.	Volts.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
a. m.																						*P. S.*
9·00	240	97	33	6	24.00	63507	...	*	†	†	†	‡	410	‡	45	...	181	†	†	...	...	...
9·30	245	98	33.5	6	24.00	65699	73.1	*	†	†	†	‡	396	‡	45	...	176	†	†	...	...	...
10·00	244	98	33 5	6	24.00	67908	...	*	†	†	†	‡	408	‡	45	101	181	†	†	...	...	4 -5
10·30	232	94	32	5.50	24.00	70123	73.7	*	†	†	†	‡	370	‡	45	102	182	†	†	...	...	...
11·00	240	96	32.5	6	24.00	72325	...	*	†	†	†	‡	390	‡	43	100	180	†	†	...	...	...
11·30	245	98	33.5	6	24.00	74547	73.7	*	†	†	†	‡	440	‡	43	102	182	†	†	...	...	...
12·00	242	97	33	6	24 00	76767	...	*	†	†	†	‡	438	‡	43	102	184	†	†	...	...	4¼–6¾
p. m. 12·30	245	98	34	6	24.00	78988	74.0	*	†	†	†	‡	410	‡	43	103	170	†	†	...	...	...
1·00	235	95	32.5	5.75	24.00	81212	...	*	†	†	†	‡	400	‡	43	102	186	†	†	...	...	5¾–2
1·30	248	100	35	6.25	23 00	83430	74.0	*	†	†	†	‡	390	‡	43	103	184	†	†	...	...	...
2·00	245	98	34	6.25	23.00	85653	...	*	†	†	†	‡	410	‡	46	106	184	†	†	...	...	4¼–7¾
2·39	241	96	33	6	22.75	87828	73.3	*	†	†	†	‡	400	‡	46	107	184	†	†	...	...	...
3·00	242	97	32.5	6	23.00	90052	...	*	†	†	†	‡	398	‡	46	107	186	†	†	...	...	5¾–6½
Total	3144	1262	432	77.75	307.75	...	...	...	...	...	...	...	5260	...	576	1135	2360	...	...	...	...	...
Average ..	241.8	97.1	33.5	5.98	23.67	...	...	...	...	...	...	...	404.6	...	44.3	103.2	181.5	...	...	...	...	...

* Not taken. Exhausting into main condenser.
† Not taken.
‡ Not in operation.
§ Not weighed.

Throttle valve wide open during test. Cut-off as determined from cards as follows: H.P. = .656; first I.P. = .658; second I.P. = .690; L.P. = .656.

The object of this test was to determine the economic evaporation of the boilers when working with dampers in uptake about one-half closed. As no observable difference developed between this and other tests, the dampers (at 11 A. M.) were opened wide, as in previous tests. The total water fed to the boilers was not weighed during the first hour of test.

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COMPANY'S STEAMER *PENNSYLVANIA*, ON LAKE HURON. JUNE 1, 1899.

Duration of test, 6 hours.

data.															Fire-room data.						
Feed water.			Water from auxil's.		Mean effective pressures.				I.H.P.					Pressures.			Temperatures.		Coal data.	
As weighed. Per hour.	Corrected for height in boiler water gage: Per hour.	Corrected for height in boiler water gage: Total	Pounds per hour.	Pounds. Total.	H.P.	First I.P.	Second I.P.	L.P.	H.P.	First I.P.	Second I.P.	L.P.	Total.	Steam in boiler.	Draft in duct.	Draft in uptake.	Fire room.	Smoke pipe.	Coal. Total.	Refuse.
24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44
lbs.	*lbs.*	*lbs.*																		
...	...	...	§	§	...	...	...	...	...	...	...	...	...	†	...	...	†	450	...	§
...	...	...	§	§	108	46.50	18.50	7.20	296.61	298.12	283.42	260.94	1139.09	†	...	...	†	460	...	§
...	...	...	§	§	...	...	...	...	...	...	...	...	...	†	2¾	.18	†	480	...	§
...	...	...	§	§	106	45.50	18.00	7.30	293.51	294.11	278.02	266.73	1132.37	†	2¾	.17	†	480	...	§
20077	...	...	§	§	...	...	...	...	...	...	...	...	...	†	2¾	.18	†	440	...	§
...	...	...	§	§	109	48.00	18.75	7.50	301 67	310.27	289.61	274.04	1175.59	†	2¾	.31	†	460	...	§
19372	...	...	§	§	...	...	...	...	...	...	...	...	...	†	3	.31	†	470	...	§
...	...	...	§	§	109	47 50	19.00	7.38	303.04	308.18	294.66	270.75	1176.63	†	2¾	.31	†	480	...	§
19017	...	...	§	§	...	...	...	...	...	...	...	...	...	†	2¾	.31	†	460	...	§
...	...	...	§	§	113	48.50	19.50	7.80	314 16	314.78	302.41	286.16	1217.51	†	2¾	.30	†	460	...	§
20570	...	...	§	§	...	...	...	...	...	...	...	...	...	†	2¾	.29	†	450	...	§
...	...	...	§	§	108	46.50	19.50	7.60	297.41	298.93	299.55	276.18	1172.07	†	2¾	.30	†	460	...	§
19614	...	98026	§	§	...	...	...	...	...	...	...	...	...	†	3	.30	†	470	...	§
...	...	...	...	...	653	282.50	113.25	44.78	1806.40	1824.39	1747.67	1634.80	7013.26	...	30¾	2.96	...	6020	14750	...
...	...	...	...	...	108.83	47.08	18.875	7.46	301.07	304.06	291.28	272.47	1168.88	245	2.795	.27	...	463.1	...	...

The following auxiliaries were in operation during this test (see table of auxiliary machinery): Air (*A*) and feed pumps (*B*); bilge (*D*) and water-service pumps (*E*); fire-room blower (*N*) and steering engine (*J*). All auxiliaries exhausting into feed heater except air pump. Condensed exhaust steam from auxiliaries was not weighed.

Valves in auxiliary piping were arranged, escape of steam about whistle and valve was the same as noted in Table II.

This test was made on the down-trip of the vessel with a cargo of 6200 tons (2240 pounds) of iron ore.

Condition of fires under boilers at beginning and end of test, the same, as nearly as could be observed.

Coal was fed to boilers by six stoker (*O*) engines, which exhausted into the ash pits.

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TABLE VI.

LOG OF TEST OF ENGINES OF MINNESOTA STEAMSHIP COMPANY'S

Draught, forward, 17 feet 2 inches.

	Time.	Steam pressures. At engines.	First receiver.	Second receiver.	Third receiver.	Vacuum.	Main engine. Counter.	Revolutions per minute.	Mean effective pressure. H.P.	First I.P.	Second I.P.	L.P.	I.H.P. H.P.	First I.P.	Second I.P.	L.P.	Total.	Temperatures. Injection.	Hot well.	Feed.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Test A.	*p.m.*																			
	4·00	195	77	26	2.25	23.50	94140	67.1	90.	39.00	15.50	5.75	224.80	229.51	217.96	191.27	863.54	44	97	194
	4·30	195	78	26	2.25	23.25	96139	66.6	90.	39.00	15 88	5.75	225.19	227.86	221.64	189.42	864.11	43	95	187
	5·00	191	76	25.5	2.00	23.25	98152	67.1	88	38.00	15.25	5.64	221.84	223.63	214.45	187.52	847.44	44	98	202
	5·30	197	79	26.5	2.375	23.50	174	67.4	91	39.50	15.75	5.75	230.43	233.50	222.47	192.14	878.54	43	97	201
	6·00	195	78	26	2.25	23.50	2202	67.6	91	39.25	15.00	5.75	231 11	232.71	213 22	192.71	869.75	43	97	202
	6·30	190	75	25	2.00	23.50	4215	67.1	86	37.50	15.13	5.50	216.80	220.69	212.76	182.97	833.22	43	95	210
	7·00	191	76	25.25	2.00	23.50	6218	66 8	86	37.50	15.13	5.50	215.83	219.71	216.75	182.15	834.44	43	95	205
	Tot'l	1354	539	180.25	15.125	164.00	...	...	622	269.75	107.64	39.64	1566.00	1587.61	1519.25	1318.18	5991.04	303	674	1401
	Av'g	193.4	77	25.77	2.17	23.4	...	67.1	88.86	38.54	15.38	5.66	223.72	226.80	217.04	188.31	855.87	43.3	96.3	200.1
Test B.	*p.m.*																			
	8·00	127	47	15.00	*	21.50	9857	51.0	58.5	23.0	9.25	3.10	112.08	102.83	98.87	78.38	392.16	44	82	224
	8·30	120	43.5	14 00	*	21.50	11394	51.2	58.0	24.0	9.00	2 50	111.57	107.77	96.57	63.46	379.37	44	80	224
	9·00	122	44	13.75	*	22.00	12895	50.0	59.0	24.0	9.00	2.75	110.83	105.25	94.31	68.17	378.56	47	102	208
	9·30	135	50	15.50	*	21.50	14442	51.6	64.0	27.0	9.25	3.25	124.07	122.20	102 33	83 14	431.74	49	110	212
	10·00	125	45	14 50	*	21.50	15980	51.3	59.5	24.5	9.00	2.80	114.68	110.23	96.76	71.21	392.88	...	...	...
	Tot'l	629	229.5	72.75	*	108.00	...	...	299	122.5	45 50	14.40	573.23	548.28	488.84	364.36	1974.71	184	374	868
	Av'g	125 8	45.9	14.55	*	21.60	...	51.02	59.8	24.5	9.10	2.88	114.65	109.65	97.77	72.87	394 94	46	93.5	2.17
Test C.	*p.m.*																			
	10·30	112	40	12.25	*	21.50	17397	45.	52.5	21.50	6.13	2.25	88.76	84.85	57.81	50.21	281.63	55	101	220
	11·00	100	35	11.25	*	21.00	18788	46.4	47.5	19.75	5.75	2.00	82.86	80.38	55.92	46.01	265.17	56	100	216
	11·30	101	35	11.00	*	21.00	20093	43.5	48.5	19.75	5.50	2.00	79.26	75.35	50.14	43.14	247.89	56	100	218
	Tot'l	313	110	34.50	...	63.50	...	...	148.5	61.00	17.38	6.25	250.88	240.58	163.87	139 36	794 69	167	301	654
	Av'g	104.3	36.66	11.50	...	21.16	...	...	49.5	20.33	5.79	2.08	83.63	80.19	54.62	46.45	264.89	55.7	100.3	2.18

* Pressure less than atmospheric—not indicated on gage.

‡ Not in use.

† Cylinder cut-offs and opening of throttle valve during the above tests, the same as noted in Table V.

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STEAMER *PENNSYLVANIA*, AT REDUCED STEAM PRESSURE. JUNE 1, 1899.

Draught, aft, 17 feet 6 inches.

Height of water in boiler water glasses. Inches.	Feed water. As weighed per hr.	Feed water. Corrected for height in boiler water gages. Per Hr.	Feed water. Corrected for height in boiler water gages. Total.	Water from auxiliaries. Pounds per hour.	Water from auxiliaries. Pounds total.	Air pump. Double stroke.	Air pump. I.H.P. H.P.	Air pump. I.H.P. L.P.	Air pump. I.H.P. Total.	Remarks.
21	22	23	24	25	26	27	28	29	30	
P. S.										Auxiliary machinery in operation as follows: Feed (*B*), bilge (*D*) and water service (*E*) pumps, blower (*N*) and steering engine (*J*). Dynamo was started at 6·13 P. M. Condensed exhaust steam from these collected and weight recorded in columns 25 and 26. Air pumps would not work satisfactorily, exhausting into feed heater, on account of reduced steam and excessive back pressure; exhaust was, therefore, sent to main condenser.
5½–4½	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	
5¾–4¾	15063	14943	14943	1499	1499	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	
3¾–5¼	15050	15266	30209	1525	3024	22	3.80	3.565	7.365	
...	...	...	...	...	...	...	...	...	...	
5¼–4	15776	15728	45937	1841	4865	...	...	...	...	
...	...	...	...	...	...	...	...	...	...	
...	15296	15312	...	1622	...	...	...	...	...	
8 –8½	...	...	...	...	...	23	...	6.914	...	Weight of condensed exhaust steam, recorded in columns 25 and 26, is from the following auxiliary machinery: Feed (*B*), bilge (*D*) and water service (*E*) pumps, dynamo (*H*), blower (*N*) and steering engine (*J*). Air pump would not work compound on account of low steam pressure. Steam was by-passed to L.P. cylinder, which, acting as a simple pump, did all the required work; exhaust connected to main condenser.
...	...	...	...	...	...	24	...	6.366	...	
4 –7½	8302	9262	9262	1630	1630	24	‡	5.942	...	
...	...	...	...	...	...	24	‡	6.048	...	
2 –7	8690	9128	18390	1571	3201	24	‡	6.791	...	
...	...	...	...	...	...	119	...	32.061	...	
...	...	9195	9195	1600.5	...	23.8	...	6.412	...	
6½–7¾	...	...	...	...	...	23	‡	7.626	...	Weight of condensed exhaust steam, recorded in columns 25 and 26, is from the following auxiliary machinery: Feed pumps (*B*), dynamo (*H*), blower (*N*) and steering engine (*J*). Air pumps operating as in Test B. Water service and bilge pumps not in use during test.
...	...	...	...	...	...	24	‡	7.215	...	
5½–9	7615	7615	7615	1431	1431	24	‡	7.427	...	
...	...	...	...	...	...	71	...	22.268	...	
...	...	...	...	...	...	23.7	...	7.423	...	

Total steam used per hour by auxiliary machinery in operation.

	Test A.	Test B.	Test C.
Steam used by air pump	7.365 × 83.18 = 612.6	6.412 × †100 = 641.1	7.423 × †100 = 742.3
Steam used by stoker motors	6 × 23.1 = 138.6	6 × 23.1 = 138.6	6 × 23.1 = 138.6
Steam used by other auxiliaries	= 1622	1600 5	= 1431
Total	**2373**	**2380**	**2312**

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SUMMARY OF TESTS OF MACHINERY OF MINNESOTA

MAY 28—

Number of table.	Date.	Duration of test. Hours.	Average boiler pressure. Gage.	Main engines. Steam pressure at engines. Gage.	Main engines. Vacuum. Inches.	Main engines. Cut-off in H.P. cylinder.	Main engines. M.E.P. reduced to L.P. cylinder.	Main engines. Revolutions.	Main engines. I.H.P.	Feed. Average temperature leaving heater.	Feed. Total pounds. Fed to boilers.	Feed. Total pounds. Used by main engines.	Feed. Total pounds. * Used by auxiliaries.	Feed. Pounds. Main engines. Total.	Feed. Pounds. Main engines. Per I.H.P.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	1899. May 28	6	242	239.4	24.35	.644	31.48	77.33	1206.71	222	122439	103509	18930	17252	14.30
2	May 30	6	244.2	238.1	23.56	.658	31.70	74.45	1169.77	213.2	116136	100167	15969	16694	14.27
3	May 30–31	6	240.8	237.2	22.73	.798	36.93	79.44	1455.04	219	146089	125711	20378	20952	14.40
4	May 31	6	245.3	241.8	22.71	.542	26.24	66.31	862.78	226.5	89566	76351	13215	12725	14.75
5	June 1	6	245	241.8	23.67	.656	32.01	73.74	1168.88	181.5	98026	...	...	...	...
6a	June 1	3	197.4	193.4	23.40	.656	25.71	67.10	855.87	200.1	45937	38818	7119	12939	15.12
6b	June 1	2	129.8	125.8	21.60	.656	15.59	51.02	394.94	217	18390	13630	4760	6815	17.26
6c	June 1	1	108.3	104.3	21.16	.656	11.87	44.93	264.89	218	7615	5303	2312	5303	20.02

* Includes steam used by stoker engines.

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STEAMSHIP COMPANY'S STEAMER *PENNSYLVANIA*.

JUNE 1, 1899.

water.					Coal.						Refuse.		Water evaporated.				
per hour.							Dry coal. Pounds.						Per pound.				
Auxiliaries.								Per hour.					Dry coal.		Combust'le.		
									Per I.H.P. main engines.								
Total	Per I.H.P. developed by main engines.	Total per I.H.P. developed by main engines.	Exhaust steam actually sent to feed heater in per cent. of total steam used for all purposes:	Per cent. of total steam used by auxiliary machinery in operation.	Total pounds.	Per cent. of moisture.	Total.	Total.	Main engines.	All machinery in use.	Total.	Per cent. in dry coal.	Actual conditions.	From and at 212 degrees.	Actual conditions.	From and at 212 degrees.	Remarks.
17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
3155	2.61	16.91	14.78	15.46	14400	3.3	13925	2321	1.63	1.92	2183	15.68	8.79	9.24	10.43	10.96	*a*.
2661.5	2.28	16.55	13.02	13.75	14200	3.3	13731	2289	1.69	1.96	2575	18.75	8.46	8.97	10.41	11.03	...
3396.3	2.33	16.73	13.08	13.95	18000	3.3	17406	2901	1.72	1.99	3800	21.83	8.39	8.85	10.74	11.32	*b*.
2202.5	2.55	17.30	13.83	14.75	11800	3.3	11411	1902	1.88	2.20	2463	21.58	7.85	8 21	10.01	10.47	*c*.
...	...	16.77	...	...	14750	3.3	14263	2377	...	2.03	...	...	8.25	9.02	...	...	*d*.
2373	2.77	17.89	10.59	15.50	...	...	...	...	...	...	...	...	...	...	...	...	...
2380	6 02	23.28	17.41	25.88	...	...	...	...	...	...	...	...	...	...	...	...	...
2312	8.73	28.75	18.79	30.36	...	...	...	...	...	...	...	...	...	...	...	...	...

a. Preliminary tests; weight of coal used unreliable.
b. Auxiliary water exhausted to atmosphere by blower equal 432.8 pounds.
c. Leak around gland of feed pump during test equal 396 pounds.
d. Total feed water weighed only during five hours of test.

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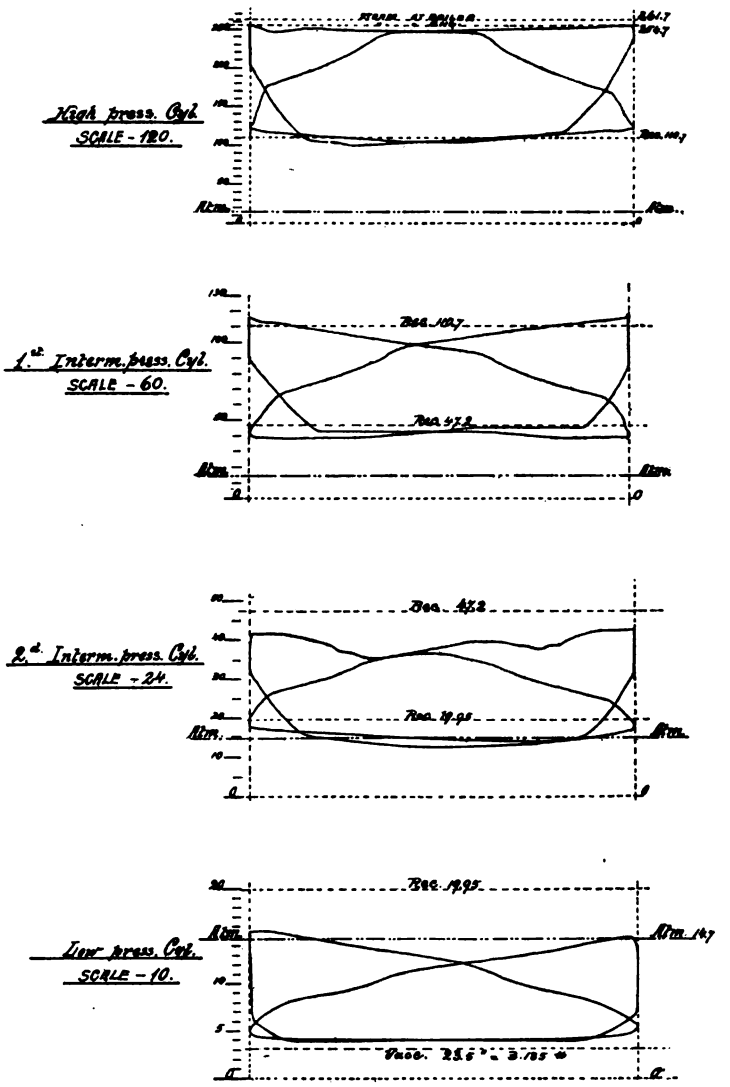
S. S. Pennsylvania. Sheet 34. a.

Card No. 7. – 5.00 P.M. – May 30. 1899. – Table II.

Average Power.



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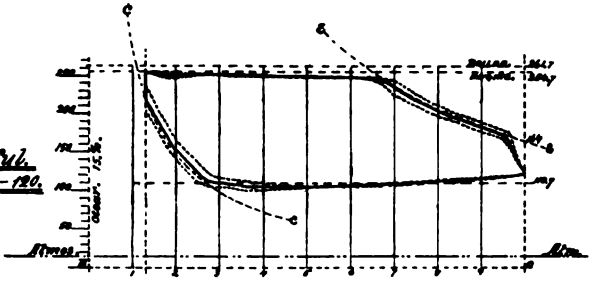
S. S. Pennsylvania. Sheet 34. b.

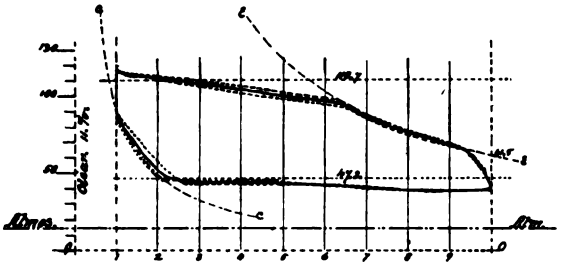
Card No. 7. – 5th P.M. – May 30. 1890. – Table II.

Average Power.

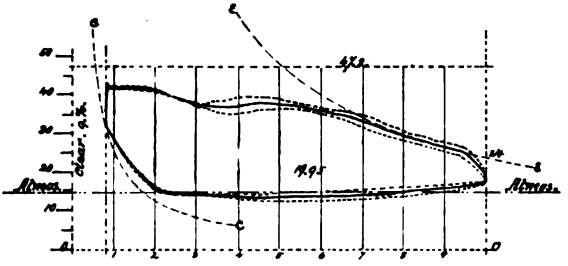
H. P. Cyl.
SCALE – 120.



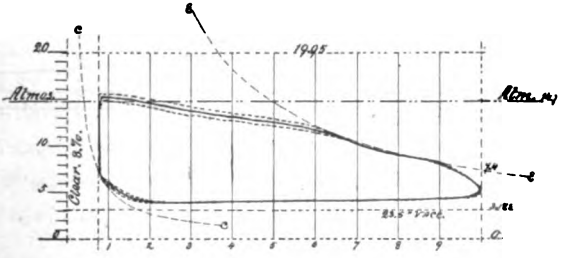
1st I. P. Cyl.
SCALE – 60.



2d I. P. Cyl.
SCALE – 24.



L. P. Cyl.
SCALE. – 10.



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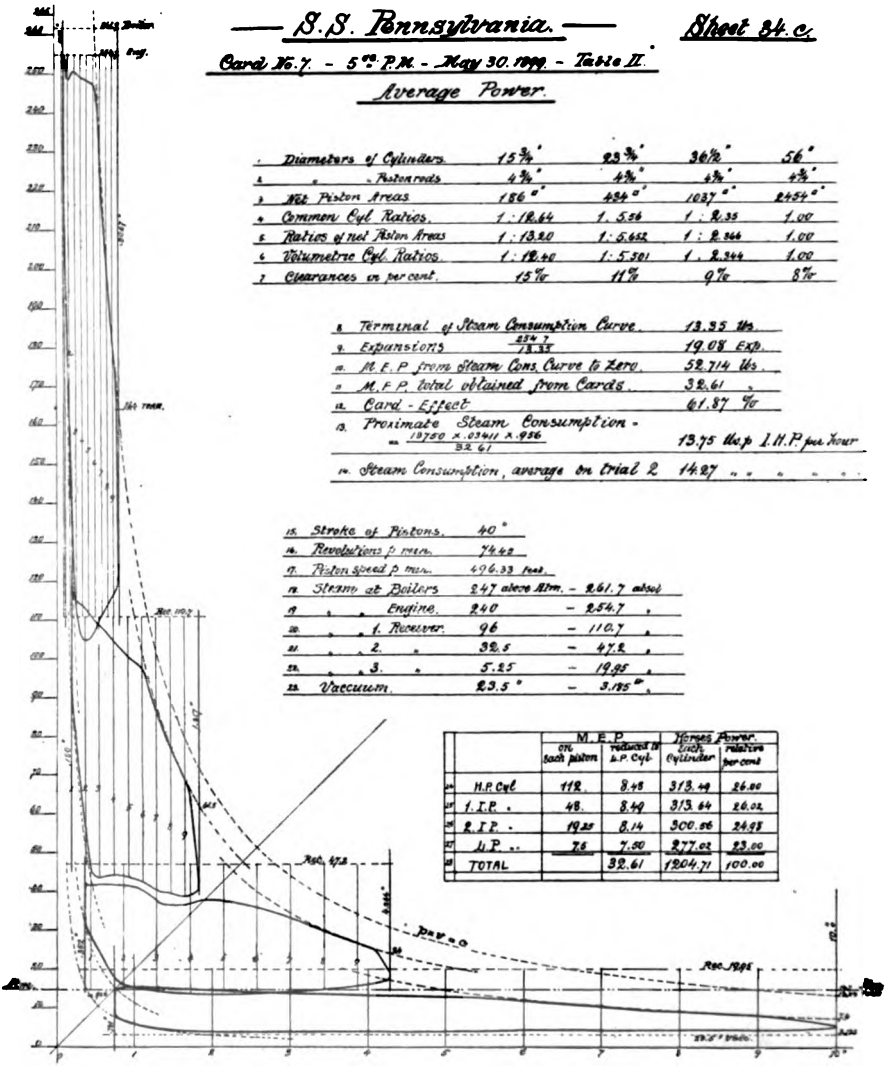

S.S. Pennsylvania. — Sheet 34.c.

Card No. 7. - 5th P.M. - May 30. 1899. - Table II.

Average Power.

1. Diameters of Cylinders.	15¾"	23¾"	36½"	56"
2. " " Piston rods	4¾"	4¾"	4¾"	4¾"
3. Net Piston Areas	186 □"	434 □"	1037 □"	2454 □"
4. Common Cyl. Ratios.	1 : 12.64	1 : 5.56	1 : 2.35	1.00
5. Ratios of net Piston Areas	1 : 13.20	1 : 5.652	1 : 2.366	1.00
6. Volumetric Cyl. Ratios.	1 : 12.40	1 : 5.501	1 : 2.344	1.00
7. Clearances in per cent.	15%	11%	9%	8%

8. Terminal of Steam Consumption Curve.	13.35 lbs.
9. Expansions $\frac{254.7}{13.35}$	19.08 Exp.
10. M.E.P. from Steam Cons. Curve to Zero.	52.714 lbs.
11. M.E.P. total obtained from Cards.	32.61 "
12. Card - Effect	61.87 %
13. Proximate Steam Consumption - $= \frac{13750 \times .03411 \times .956}{32.61}$	13.75 lbs. p I.H.P. per hour
14. Steam Consumption, average on trial 2	14.27 " " " " " "

15. Stroke of Pistons.	40"	
16. Revolutions p min.	74.42	
17. Piston speed p min.	496.33 feet.	
18. Steam at Boilers	247 above Atm.	- 261.7 absol
19. " " Engine.	240	- 254.7 "
20. " " 1. Receiver.	96	- 110.7 "
21. " " 2. "	32.5	- 47.2 "
22. " " 3. "	5.25	- 19.95 "
23. Vaccuum.	23.5"	- 3.185 "

	M.E.P. on each piston	M.E.P. reduced to L.P. Cyl.	Horses Power. each Cylinder	Horses Power. relative per cent
24. H.P. Cyl	112.	8.48	313.49	26.00
25. 1. I.P. "	48.	8.49	313.64	26.02
26. 2. I.P. "	19.25	8.14	300.56	24.98
27. L.P. "	7.5	7.50	277.02	23.00
28. TOTAL		32.61	1204.71	100.00

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CONCLUSION.

Engine.—From the results of these tests, it is apparent that the steam consumption of the quadruple-expansion engine of the *Pennsylvania* shows no economical gain over ordinary engines of the triple-expansion type as now designed for pressures approaching 250 pounds. Several assignable reasons may be advanced as accounting for this. It is probable, however, that the most cogent factor lies in the ratio between the first and final cylinders, which should have been larger for economical working at the horsepowers developed at the usual speed of the vessel.

Typical indicator cards from the main engine, and the combined card, are herewith appended.

Auxiliaries.—The prevalent custom on vessels engaged in traffic on the Great Lakes has been, until recently, to attach all necessary auxiliary machinery operated in connection with the main engine (air, feed, bilge and water-service pumps,) directly to it. Although not so convenient or satisfactory in many respects as compared with independent auxiliaries, this plan has unquestioned advantages in steam economy.

With the general introduction of water-tube boilers, however, and the consequent practical necessity for independent feed pumps, which, in turn, led to the installation of feed-water heaters, the loss in economy within limits due to independent auxiliaries has been largely overcome.

As before stated, all auxiliaries on the *Pennsylvania* are independent. Those run regularly when the main engine is in operation, viz: air, feed, bilge and water-service pumps, are of the compound type, and show fair economy in steam consumption per unit of power. The economy of other auxiliaries, except fire-room blower, dynamo and steering engines, is unimportant, since they are only periodically in operation and generally for small intervals of time.

Of the auxiliaries above mentioned, the dynamo engines—each of which consists of a single cylinder with piston valves—are apparently the most expensive in steam per I.H.P. developed. It is to be noted, too, that the tests show considerable difference in

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the economy of the port and starboard engines when carrying about the same load. This, no doubt, is attributable to steam blowing directly into the exhaust from faulty fit of the port engine piston valve.

During the experiments the effect of increasing the temperature of the feed water to about 225 degrees, or above, in the heater, was noticed to be detrimental to the efficient action of the auxiliaries. At such times, on account of the excessive back pressure in the heater shell, much readjustment of the auxiliaries' throttles was required, causing "kicking" of the various pumps, and necessitating constant care. The upper limit of feed-water heating for thorough efficiency on the *Pennsylvania* seems to be about 200 degrees, amounting to an average rise in temperature of the water taken from the hot well of, approximately, 95 degrees. From the tests it is seen that this result is accomplished with the auxiliaries consuming about 10.5 per cent. of the total steam generated by the boilers. The cost, therefore, of operating independent auxiliaries in connection with an exhaust feed-water heater, as compared to attaching them to the main engine, when the above percentage is not exceeded, is only trifling, and more than offset by the many obvious advantages of independent machines.

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A STUDY OF THE ENERGY OF THE BOW WAVE.

By Marston Niles.

"It would seem that a certain pride in mathematics has prevented those engaged in these investigations from availing themselves of methods which might reflect on the infallibility of reason. * * * As regards the direct object in view, the revelation of the actual motion of fluids, the research has completely failed. And now that generations of mathematicians have passed away * * * the simplest problems of fluid motion are yet unsolved."—Professor Osborne Reynolds, *Proc. Royal Inst.*, February 2, 1877.

When a ship is in rapid motion certain forms and forces are developed in the surrounding water. The prevailing opinions respecting these are based upon the labors and conclusions of a long line of distinguished mathematicians and experimenters, and are in substantial harmony with each other.

It is my desire to set forth sundry reasons for believing these opinions, together with their mathematical bases, to be in almost every respect erroneous, and for believing the conclusions which have been drawn from certain experiments to have been deduced in an improvident manner.

Wave resistance may not improperly be conceived as a fringe, seam, or peculiar selvedge along the side of the fabric of stream resistance. Before the warp and woof of this fabric can fairly be unraveled it is necessary to detach the selvedge. Therefore we must first dispose of the matter of wave resistance.

The following picture is a reproduction of one given by William Froude. I have added letters and figures to the picture.

The height of the waves in this figure was made twice their height in the experiment which the figure is supposed to represent. This he did for the sake of distinctness.

The water rises into waves because it is struck by the advancing bows, or by other water which, having been struck by the bows, has taken upon itself somewhat of their contour. On

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being thus struck, it is displaced. In an ahead-and-sideways direction it cannot entirely be displaced, because other water ahead-and-sideways does not readily give place to it. Therefore relief is found in a plane above the level, where there is room abundant. Thither it rises, albeit unwillingly and against its gravity. Having now been hove up above the position of equilibrium, it next, at once, proceeds to sink as far, or nearly as far, below that situs. In this rising and sinking, and in continuing to vary from the plane of equilibrium, it begets two sets of water agitations, both of which have been called waves, although only one set consists of waves in fact.

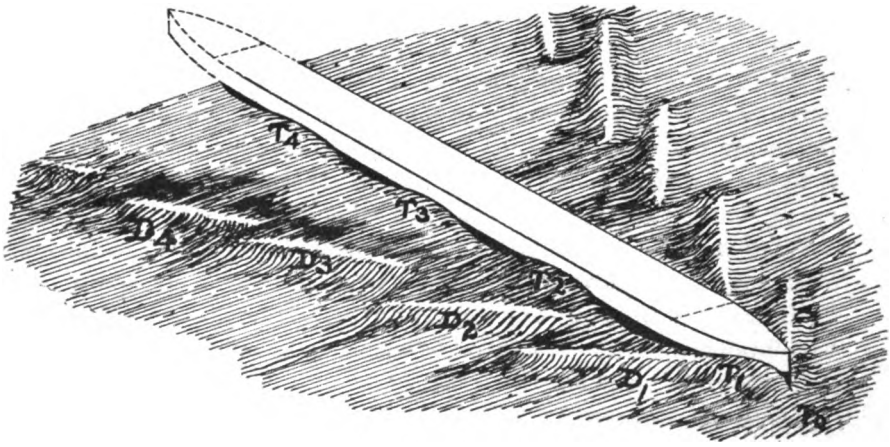

Fig. 1.

The foregoing figure is worthy of the closest study. In it may be roughly perceived, as far as the ship's forebody is concerned, the sum and substance of the principles of wave resistance, or, in other words, the causes of that waste of horse-power which consists in the useless hoisting of a weight of more than a quarter of a ton to the cubic yard, a waste which at high speeds becomes enormous. At her stern, a ship begets two other sets of waves resembling the forward systems, in producing which a clash between water and water replaces the clash between bow

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and water which took place forward. This makes an additional waste of horse-power at the stern strictly proportional to the cubical mass of the waves made there. Neither of the two sets of stern waves is represented in the figure.

The type of ship here pictured is a rather old-fashioned one, with a long, parallel-sided middle body. This type was chosen, not for the excellence, but for the badness of its form, and for its exhibiting the most malignant developments of wave-making tendencies. I have marked each wave on the starboard side with a number. The skew-shaped or scantling ones are the so-called "diagonal" waves. They are marked D^1, D^2, etc., etc. The masses whose outlines are seen in wavering form upon the ship's side are the thwartship or so-called "transverse" waves. They are marked T^1, T^2, etc., etc.

In the following discussion, for the sake of convenience, the term "bow wave" will be used to signify merely the transverse element of that wave, and will exclude the diverging wave, unless the contrary is directly indicated.

THE TRANSVERSE BOW WAVE.

All the authorities with which I am acquainted hold, variously, that the whole or a part of the energy which throws up the bow wave is gotten from the waves which are behind it. Those of them who have treated the subject in the fullest manner, trace an even half of this energy to the waves behind.

The question is far from being merely one of theory. If the authorities are in error, a radical departure from the prevailing water lines is called for. I shall endeavor to show that the accepted theory is contrary to the fact, and that the subsequent members contribute no energy whatever to its formation. The whole energy is traceable to the reaction between the ship's bows and a certain crowded mass of water, and is furnished by the ship alone, and by the ship immediately.

Professor Rankine holds that the principal loss of power at the bow takes place through the diagonal wave, and that the transverse train, once started, is not a cause of sensibly increased resistance. He bases this conclusion upon the circumstance that

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long waves, such as are raised by ships, are capable of traveling great distances without sensible loss of energy. It is clear that he looks upon the transverse train as traveling with the ship, as retaining at the bow nearly all the energy which it possessed further aft, and as delivering up the whole of it to the bow wave, the leader of the system; and he considers that into the bow wave is received, for and toward the propagation of the system, all the system's energy, save such as goes abroad in the mass of the divergent wave, and save, of course, what may be lost in friction. ("Shipbuilding," pp. 79, 80.)

Professor Lamb lays down a principle identical with Rankine's, except that he treats only of the case where the train consists of a bow member and a stern member without any waves between. "A free surface" of the fluid, says he, "at a great distance from it also has little effect on a solid. The case is otherwise, however, when the solid is only partially submerged, *e. g.*, a ship. One effect of the motion is to make the pressure deviate from its statical value; to increase it, for instance, at the bows and at the stern, and to diminish it amidships. Hence the level of the fluid is disturbed, and there is *an elevation of the water at each of the former points, and a depression between.* A wave like this accompanying the ship would, of course, *cause no loss of energy* beyond what is necessary to maintain it against viscosity.* But we have also waves produced which travel over the surface, and carry off energy to distant points of the fluid. The energy thus dispersed must, of course, come directly or indirectly from the ship; and the loss from this cause contributes a special form of resistance called 'wave resistance.'" (Motion of Fluids, p. 247.)

Nearly identical with the doctrines of Professors Rankine and Lamb is the view of the great constructor Sir William White, who says, "When such a ship has reached her uniform speed, and the waves have been *fully formed*, the *maintenance* of these waves will require a certain expenditure of force which measures the wave-making resistance. The case is parallel to that of the

* "This is easily seen by impressing on everything a velocity equal and opposite to that of the ship, and so reducing the case to one of steady motion."

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deep-sea waves (described at p. 217), which travel over immense distances without any great loss of speed, but with this important difference, that, whereas the ocean waves *gradually become degraded*, the waves accompanying ships, under the favorable circumstances described, *are kept to their full height*." (Nav. Arch., p. 455.)

In his admirable paper on "*Leading Phenomena*," etc., the doctrine of Mr. R. E. Froude is, that half the energy of the bow wave comes from the train abaft it, and that half is contributed by the ship. He bases this doctrine on the facts that "a system of deep-water waves does not travel as fast as the individual waves composing it," and that "the energy represented by the wave motions is transmitted from particle to particle in the direction of the travel of the wave by the mechanical conditions of wave motion; but this transmission is only effected at half the speed of the individual waves." "We now see, then," says he, "that the work a ship has to do in maintaining a wave system, whether of transverse or diverging waves, is, in fact, equivalent to adding to the system one new wave for every two wave lengths she travels." (Leading Phenomena, etc., Trans. Inst. Nav. Arch., 1881.)

In the *Proc. Inst. Civ. Eng.*, Vol. XXXII, p. 243, we find William Froude declaring that "it is now well known that if the divergent waves generated by the ship *in transitu* were excluded (which with a well-formed ship moved at a moderate speed were trivial), these frictionally-created movements were responsible for the entire resistance which the ship experienced." That is to say, he fully accepted Rankine's theory that when the transverse train has been once established, no energy, or no considerable energy, is expended in its maintenance, except what is necessary to supply the loss occasioned by the divergent waves. It is not strange that William Froude accepted Rankine's inference. He was, perhaps, disposed to look on Rankine's theories in general as he looked upon the law of gravitation; this is why we find him taking as quite for granted the reliability of Rankine's theory as to the resistance of the bow wave. This magnificent

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man had work on his hands more important than even the laying out of theories. His bent of mind was toward positive ascertainment rather than toward the drawing of inferences. Apparently it was his custom to lay light stress upon divining what the fact *ought to be*, and to lay great stress upon finding out what the fact *is*. Principles were to be evolved from stuffs and shapes in the external world, through, and not out of, changes of form in the substances of the brain. Perhaps he believed he had no business to think in respect to a matter in which he could make it his business to behold. Theories were well; but the theory adopted by the things themselves under consideration, as a rule for their conduct in a given situation, was the best theory for the student of phenomena to adopt, and the student was to find out, by experiment and not otherwise, this theory. Froude willingly bowed to Rankine's hypothesis, until the facts should present him with another.

Professor Durand agrees substantially with Mr. R. E. Froude, in that he says that "the group as a whole may be considered as the expression of a certain distribution of energy, and hence the velocity of the group may be considered as the velocity with which the energy is propagated, as distinguished from the velocity of the individual waves. It must be considered, therefore, that in waves of trochoidal character the energy is propagated at only one half the velocity of the waves themselves. * * * It seems allowable to assume for the waves of this system such further properties of trochoidal waves as may be convenient for their investigation. * * * It follows that for every two wave lengths run the ship must supply the energy necessary to the formation of one wave. Let us assume that one-half the energy is naturally propagated with the form, and that one-half must be made up by the ship." (Resistance and Propulsion of Ships, pp. 89, 94, 96.) But Professor Durand is careful to observe that "the exact fraction of energy which falls astern relatively to the ship will depend on the geometrical character of the wave; and it must not be considered that the ratio $\frac{1}{2}$ is anything more than an approximation, which, however, may serve for illustrative pur-

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poses" (p. 95). Therefore, the agreement of Professor Durand with the other commentators appears to amount only to this, viz: that the bow wave is produced in part by the ship and in part by the train abaft it.

Mr. D. W. Taylor enters into this subject with his customary exhaustiveness. He supposes the transverse system to consist of trochoidal waves marching steadily with speed equal to that of the ship. "Advancing into still water," *i. e.*, into the motionless fluid just ahead of the bow, "such a system carries its potential energy with it; but the kinetic energy of the new particles, constantly set in motion, must be derived from work done by the wave resistance of the ship." He makes the kinetic energy of the mass, due to the rotation of its particles, to be precisely equal to the potential energy of the mass, due to its mean center of gravity being raised above the position it would occupy if the water were at rest. Letting w equal the weight per cubic foot of the water, and l the length of the wave, and b its breadth, and H its height from crest to hollow, he makes the kinetic energy, which must be furnished afresh by the ship, to be equal to $\frac{1}{16}\, w\, b\, l\, H^2$; and this same $\frac{1}{16}\, w\, b\, l\, H^2$ he makes equal the potential energy which the transverse system transmits to the bow wave and contributes to its formation. (Resistance of Ships, etc., pp. 43–45.) Thus in his dividing equally the burden between the ship and the train, he is entirely at one with Mr. R. E. Froude and with Professor Durand. But he furnishes a fullness of formula in which Mr. R. E. Froude is lacking. Upon this subject Mr. Taylor may be regarded as bringing up to date the matured and clarified doctrine of the mathematicians.

The claim, then, of the authorities is, variously, that (*a*) the whole, (*b*) the half, (*c*) some part, of the energy that throws up the transverse bow wave is put into it by the waves behind it. That is to say, that in Fig. 1 (page 592), the force or work necessary to bring level water like the water marked T^0 to the height and character of the form marked T^1 (understanding by T^1 so much of the wave as does not belong to D^1) is wholly, or in half, or in some part, contributed by the waves T^2, T^3, T^4, aided per-

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haps by other waves which are supposed to be coming up still further astern and which are not exhibited in the picture.

The seaman can hardly admit this claim.

To affirm that at a given instant the ship is furnishing but half the energy which creates the wave T^1, and that the troop T^2, T^3, etc., are furnishing the other half, is to affirm that at each and every instant, or during a whole unbroken voyage—as, for example, from New York to Liverpool—the ship furnishes but half the energy, and the troop itself the other half. For, excepting at the time of gaining headway at the beginning of the voyage and losing it at the end, the instants are all alike and the waves all alike. The whole track of the ship from one port to the other is made up of waves exactly like the above-pictured bow wave and its troopers.

If the mathematicians should admit that the ship has primarily energized the troop, but allege that nevertheless she has constituted the troop a depository of energy to be by it surrendered from time to time for application upon the bow wave, the seaman will wish to know by what track or channel the troop receives the energy, and by what track or channel it is handed back. For it must appear to him that whatever energization the troop has received has been conveyed to them by and through the bow wave itself; or, more strictly speaking, by and through bow waves of elder birth indeed, but each one of them exactly like the current or now-existing bow wave.

This indeed will hardly be denied. But if the energy required for casting up the current bow wave has been furnished wholly or in part by the following troop, the troop having been energized for that purpose by previous bow waves, we may lawfully strike out the troop as being a mere *conduit* of energy, and in contemplation we may short-circuit this contributed energy by passing it directly from an earlier bow wave, or from several earlier bow waves, to the current bow wave. Short-circuit or long-circuit, this theory makes an earlier bow wave a purveyor of energy for a later bow wave, and it throws upon the earlier bow waves a burden of undue gravity, and it unduly lightens the burden of the current bow wave. In an extended voyage a

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fearful charge would be resting upon the earlier bow waves, and thereby upon the engines during the earlier part of the voyage. It is upon the engines that the demand really tells; for the ship's hoard of energy or impetus lasts for a few moments only, and must be constantly replenished by the engines.

In any case, it would be intolerable that a stream of energy should have been pouring aft from the earlier bow waves into the troop in order to energize through them the current bow wave; for the current bow wave is in turn bound to hand aft to the troop a stream of energy for the behoof of future bow waves; hence whilst it is engaged in receiving *from* aft its incoming stream of energy it would be at the same time engaged in delivering *toward* aft an out-going stream, and these two streams could not but clash and they both would be destroyed.

How complicated and how contradictory is this theory! How simple, on the other hand, are the facts! The ship's engines, through fresh momentary thrust, assisted by previous thrusts which lie hoarded away in the ship's impetus or *vis viva*, deliver each instant to the bow water the quantum necessary for the push and hoist of that instant. This hoist and push instantly make the water into the bow wave of that instant. The water of the bow wave, on falling from the height which it attains, bounds and rebounds upon the water-bed during succeeding instants, the ship's side meanwhile passing it gradually by; thus the adjacent water is rumpled into the semblance of a troop of waves, and, indeed, of a troop which appears (but only appears) as if it were moving forward and dogging the heels of the bow wave. In point of fact, all energy passes from the original bow wave to the troop behind it. This troop consists merely of echoes or reboundings on the part of the masses of water which earlier have occupied the bow wave position, and whilst in that position have acted the part of leading or bow wave. It is clearly impossible that any energy whatever should pass from the troop to the bow wave. The bow wave truly is the cause of the troop; *i. e.*, previous bow waves have caused the troop. The troop are constitutionally in dependence upon the bow wave for original existence as well as present subsistence.

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FROM WHERE DOES THE ENERGY COME TO THE TROOP?

If energy is to pass from the waves that follow, into the wave that leads, this energy must first be gotten into the waves that follow.

From whence is that energy derived? From the afterbody? No. The afterbody in many cases makes, visibly or invisibly, a hollow of water, a sagging of water below the level along the counter. Now a hollow shows, not energy, but a defect of energy. Even if this last be not agreed to, it will be agreed that whatever demand is made by the hollow is satisfied by the rise or wave astern of the hollow—a wave rendered possible by the hollow. The up-flowing and convergent clashing streams whose tardiness of motion has caused the hollow, now, on the contrary, fashion themselves into the stern wave. They rush upward and rush inboard, and on the front of that wave build it up, prolonging it exactly one inch for every inch that the ship advances. As the stern of the ship advances, the under streams rise from beneath her and the side streams clash abaft her, and they all rise into a heap which is constantly added to at the front of the heap, and just as fast as the stern moves forward. This statement contains pretty nearly the whole doctrine of the stern wave. Each mass of stern wave is begotten from water just forward of itself, and its energy passes to posthumous offspring following at the heels of the next succeeding mass of stern wave. None of that energy can spring from the stern wave toward the fore and go forward to the bow.

Nor does the energy of the waves that follow the bow wave come from the waist. There is nothing in the waist that can throw up a wave. Or if, as in the torpedo boat at high speed, the waist aids in throwing up the wave, then the waist is, so far, a continuation of the bow, and the waist's function is a continuation of the function of the bow.

Still idler would be the supposition that the screw gives the transverse system of waves its energy. The push of the screw upon the water is sternward, and it is reckonable in terms of slip. In another way, indeed, the screw's motion does impart the energy, viz: through the bows, for it drives the bows against

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the water; but it does not avail to cast up the troop, except by casting up the bow wave which itself casts up the troop.

The origin of the bow wave is simply this.—Some portion of certain water which, before the bows reached it, lay stretched abroad for perhaps a ship's breadth between certain outboard water and a line projected due forward from the cut-water, becomes, when the expanding bow-contour reaches it, crowded for quarters. Instantly it is compelled to give up to this advancing contour some of its in-and-outboard or y dimension, and also some of its fore-and-aft or x dimension, and consequently is compelled, by the incompressibility of water, to take up an increased vertical or z dimension. This mere increase of vertical or z dimension is what we call the bow wave.

Since the bow wave consists of the raising higher of a substance that has gravity, it obtains thereby a potential energy due to gravity and to elevation. As soon as its particles, moving aftward, pass in succession a certain critical point on the side of the bow, they fall in succession with an energy that is actual.

On falling, they displace other water; the water thus displaced is raised, and in rising acquires a potential energy. When this last subsides, it subsides with an actual energy, and, in subsiding, raises the original wave water (which meanwhile has relatively moved aft) to a point of potential power again.

These alternations of energy, actual and potential, between masses of water, constitute the whole of the energy of the transverse train. This whole energy comes from the reaction between the bow and the water there, the energy of the reaction being converted immediately into potential energy in the bow wave to an amount proportioned to its mass and elevation.

To go into detail.—The as-yet-humble water just ahead of the bow obtains the wave elevation by virtue of (*a*) the push of the screw blades against the reacting water behind the blades; (*b*) the rigidity or uncrushableness of the ship between the thrust block and the spreading contour of the bow; (*c*) the unyieldingness of the bow structure to the water which rushes against it; (*d*) the reaction of certain well-outboard water against the

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outboard pressure of crowded water lying between it and the advancing bow—a reaction partly owing to its inertia and partly to viscosity, which viscosity has hitherto caused both itself and the intermediate or crowded water to refrain from earlier swerving duly sideways in obedience to pressure from the bow during the time while the bow was still distant; for, had there been due previous swerving, there would have been no congestion and, therefore, no wave; and, finally, (*e*) the inertia of the water bed, consisting of the lower strata which are unable so quickly as in a single instant to sink beneath the weight of the hill of water that overlies them, or to distribute in widely radiating directions its pressure and their mass.

HOW LONG WOULD THE TROOP'S STORE OF ENERGY LAST?

Let us view the matter from a somewhat different standpoint. Assuming for a moment that there is energy which now is pushing from the following train of waves towards and into the leading or bow wave, it still is true that there has been a time when the ship having but just reached full headway and but just finished the starting of the train, the output of energy pushed (as the commentators contend) into the bow wave, was the first full and perfect installment of energy. Let us now place ourselves there at the instant at which that first installment of energy was duly handed forward, and at which it empowered, or at least assisted, the bow wave to continue its career. The first installment having now been furnished forth by them to the bow wave, from where are the would-be helpful waves abaft it to get energy out of which to hand forward to the bow wave the next installment, lacking which the bow wave would, according to the commentators, surely dwindle? From where shall those following waves get the third, the fourth, the thousandth, the millionth installment which they must hand over? For these will all be called for in a long, unbroken voyage. A certain store of energy, indeed, the train may at the outset have acquired from some quarter quite unnoticed during the wave confusion which prevails while acquiring headway. But this outfit of energy cannot last forever, nor miraculously be handed forth in perpetuity, like eggs from

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the sleeves of a conjuror. From somewhere must come the supply which the train is to be constantly delivering over to the fore. I ask, is there any possible source for it but the bow wave itself? If not, will the commentators seriously contend that the troop gets energy from one bow wave, and then hands it over to the next bow wave? Remember there is really no division of the bow wave into parts. It is simply one continuous rise of water from New York to Liverpool. The eye is merely playing the same old trick upon the brain.

THE ENERGY IS BRED WHERE THE RESISTANCE IS.

Let us view the matter in a more fundamental manner. It is forward that the ship is moving, according to the wont of ships. It is when she is in forward motion that these waves are begotten. They are quite unknown with ships at rest. To all forward motion there is wave resistance. If the water should indeed be running forward at the ship's own swinging gait, as when the ship drifts bows-on in a current, there would be no wave resistance, and therefore no bow wave. Clearly the bow wave is the offspring of wave resistance. Now the bow is that part of her that encounters wave resistance, and indeed manufactures that resistance, and at that very spot, viz: the bow; and there at the bow in fact we behold the bow in the act of producing the bow wave. It is the business of the bow and of its resistance to make that wave, and truly they are equal to their business. We should be carrying coals to Newcastle if we brought supplies of energy from abaft or elsewhere to assist the operation of piling up bow water into a bow wave. If from abaft we brought up some additional supplies of energy and put them at the labor, we should shortly roll up a wave which would overrun the forecastle and which no engines could overpower.

THE ONLY WAY TO TRANSPORT FORWARD A TROOPER'S ENERGY.

But if still we are determined to bring this energy forward, we cannot at any rate bring it through the water. There is no means present for transporting it through the water, for none of these transverse waves have the circular motion which the ocean waves

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have, and by which alone the ocean waves are enabled to trundle onward their energy as a girl does her hoop.*

The transverse waves which follow are mere subsequent bouncings, ballotings, reverberations, rëechoes, of the leading wave. They are mere effects of the leading wave. They cannot face about and pretend to be its cause. There is only one way in which an echo of the bow wave can send its energy forward. It is by our choosing for the performing of its reverberation a spot in which its particles, in rebounding upward under the stress of gravity of other particles, will press against the up-and-aft-and-outboard-sloping under surface of the afterbody near the stern; a spot in which, but for the up-swelling motion of these particles, there would now be a hollow and a defect of pressure near the stern. If we can contrive it that just here shall be where they rise upward, they now will help to urge the vessel forward, and, as a later-rising generation, they will accomplish, if I may say so, a genuine if tardy restitution for the evil formerly committed by their lineal ancestor at the bow. It is this echo work of which Mr. R. E. Froude treats in his admirable paper of April, 1881; yet I cannot but think he would have made the matter far clearer had he first brought to view, with proper apparatus, the actual up-motion of the particles of the echo, and had he then pictorially or graphically resolved the energy of that motion into its vertical, its in-and-outboard, and its beneficial fore-and-aft components—in other words, had he resolved into its component x, y and z elements the line normal to the under afterbody surfaces which represents the resultant total onset and effective pressure of the rising particles of the stern wave made to form at the proper spot.

IT IS IMPOSSIBLE TO CARRY OUT THE THEORY.

When Mr. R. E. Froude observes that the work which a ship has to perform in respect of the transverse train is only "that of continually *lengthening* the system at half her own speed," *be-*

* This subject is too complicated to be dealt with in the present paper. For present purposes it may be sufficient to beg the reader to observe that the waves of the transverse system have not, as those of the ocean system have, the forward lunge along the crown, and the backward surge along the trough, which distinguish all rotary waves. Notice a boat, or even a chip, floating in the transverse system.

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cause "the speed of the system is exactly half that of the waves," it is impossible for seamen to follow the thought-process by which he advances.

If I am traveling by express and cannot produce my ticket, and have by me in cash only half the fare, it will not avail me that my son is traveling by accommodation train a little later and carries as much more cash in his pocket book.

If my horse must beat 2·12 in order to win a race, it cannot help me that I have also in the same start a promising colt of his that can be counted upon for a speed of four minutes and twenty-four seconds.

If I hope to get ten knots out of my steam launch, I shall not borrow my neighbor's, which is good for five knots only, and let that puff and toil in tow behind me to help on. If, for appearance's sake, I must not cast her off, I shall beg that she disconnect, or better, hoist her screw, and by all means do the least she can in assistance.

In like manner, if the bow wave has to drag, at a certain speed, a lot of hangers-on which are unable to go of themselves at more than half that speed, the bow wave is getting no help, and it will do better to cut adrift from them and proceed quite alone.

Besides which, to double the speed of a wave takes more than double the energy. In order for a wave to move twice as fast as another it must be four times as long. If four times as long, it will be four times as broad, and four times as deep. To lengthen the system by doubling the speed, as Mr. Froude proposes, would require thirty-two times the power, in lieu of twice the power. If the reader is unable to agree to an increase of thirty-two times, he nevertheless will probably agree to a far greater increase than merely twice.

DO NOT CRY OVER SPILT MILK.

I think the point of view from which it has been customary to regard the subject of ship waves is one which predisposes us to see every portion of it in a wholly false light. Mr. R. E. Froude says: "The question is not, however, What expenditure of energy must have been required to create the wave system, but

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What rate of consumption of energy is involved in its maintenance when created." I think seamen, on the contrary, will say, Let us be very particular and deal with each wave quite distinctly, and not with systems and their maintenance. I think they will say, When once the energy has been expended in creating a wave it is a dead loss to us, and we do not care what becomes of the wave or its progeny, unless there is one of them that we can put in harness near the stern. If the wave has actually been raised, this means that the mermaid has already sneaked away with all the horsepower that she can steal. What the echo water does with itself afterward is of absolutely no moment. That it is of absolutely no moment may well appear from the fact that its moment is merely up and down, thus self-destroying, as far as its ultimate effect is concerned. All the agitations that are subsequent to the original mischief are only as the thunder to the lightning, or as the report of an occurrence is to the event itself. If engine power has been diverted for the hoisting of water, it is useless for us to watch the train of waves thereby created, or to speculate how long a dance they have vigor to maintain—excepting always, of course, that if we can catch one of the rascals near the stern, we shall get out of him, for our use, all the strength that remains in his legs. The seaman will fix his whole attention upon the *leaders* in the transverse systems, whether the bow system or the stern system. It is a waste of time and, worse, a wasting of useful powers of observation, to pay any regard to "the maintenance of a system," unless for the purpose just stated. Yet Mr. Froude's words are susceptible of a reasonable interpretation also.

THE OCEAN WAVE.

With the ocean wave, it is very true, the water on the front face of the wave is rising, and its rise does, in a certain sense, help in the raising of water which at present is in front of the wave. If this is the case with the ocean wave, why, it may be asked, is it not the case with the second member of the transverse system, and why does not the energy present in that member aid in the casting up of the transverse bow wave just ahead?

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Without entering into the differences of the two systems with regard to internal structure, we may note with the eye a sufficient difference between them for constituting a reason why this should not be the case. In front of the ocean wave we observe a hollow. This hollow is, for wave-making purposes, just as useful as if it were a height from which the water could fall, for it represents, in its own depression, an elevation of other particles—an elevation due to that depression. The elevation of those other particles gives them an energy in falling which helps the water to rise on the front face of the wave, just behind the depression. The hollow in front of an ocean wave, then, is indidirectly a source of energy for the wave, just as much as the height which is attained by its particles is directly a source of energy for a repetition of the wave. For an overshot wheel we can get a fall just as well by digging out the bed below as by throwing up a dam above.

Observing the water in front of the bow wave, however, we find no such depression there, and, consequently, no such source of energy. Between this leading wave and the wave next abaft it, we do, indeed, find such a depression; it is a depression owing to the energy with which the water which has just been hoisted along the front of the transverse bow wave, has fallen from the height to which it was hoisted—falling perpendicularly thence, although the marching forward of the point at which successive particles begin to fall has the effect of producing an outline of falling particles which slants diagonally downward and sternward, and thereby causes an appearance as if the falling water were gushing sternward as well as downward. The depression, then, between the first and second members of the transverse system is, with respect to the first member, in the nature of mere effect, and is not in the least a cause. To the second member only does it stand in the relation of cause—of cause to a certain extent; for although the second member has a certain vigor of its own, being the rebound of particles which an instant earlier had fallen from the positions successively attained at the crown of the *then* first member of the system, still, this second member would be an enfeebled echo of the previous bow wave, were it

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not reinforced by the energy implied in the depression between itself and the new bow wave. The energy, therefore, involved in the hollow does not transfer itself forward, or aid in lifting the front half of the bow wave. The weight of this wave must be lifted by a dead lift, it having in front of it no hollow to serve as a source of energy; and the lift must be furnished wholly by the present push of the screw and by the past pushes of the screw, whose energy lies hoarded in the impetus or *vis viva* of the ship's motion. In Fig. 1, observe that forward of T^1 there is no depression, but there is a depression between T^1 and T^2.

THE PREVAILING THEORY CREATES ENERGY OUT OF NOTHING.

Still another instructive side-view of the established theory may be taken as follows.—Neither a difference in model nor a difference in speed can change the essential character of the transverse system; but with all vessels and at all rates of speed this character remains the same. This being the case, it may advantage us to consider certain facts brought out by William Froude in experiments on "Parallel Middle Body" (Trans. Inst. Nav. Arch., March, 1877), and to consider whether these facts are consonant with the theory that a considerable portion of the energy of the transverse system passes forward into the leading or bow wave.

It was shown that a certain vessel 170 feet long, when towed at 14.43 knots, experienced a "residuary resistance" which, skin-frictional resistance having been subtracted, amounted to only about 7¼ tons. This was because the first echo of the bow wave, abaft, was produced in the most favorable location for pressing the afterbody forward. The same vessel, however, when lengthened to 220 feet by insertion of parallel middle body, and towed at the same speed, experienced a "residuary resistance" which amounted to about 16¼ tons, or more than double the former resistance. It was shown that this doubling of resistance was owing to the circumstance that the echo was then produced in the least favorable location for pressing upon the afterbody.

It is true that data which for my present purposes are most important, are lacking in his report; therefore it is impossible

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to draw a perfectly reliable deduction. There is matter here, however, which calls for reflection.

The echo suffered undoubtedly a great loss of energy from friction and external diffusion as it passed aft. Moreover, its energy was not able to be applied to the afterbody with perfect effectiveness, as in the case of normal-surfaced water pressing with the insistence due to its own gravity and the gravity of neighboring outboard water which is backing up that pressure; since even during the application of its pressure the echo was falling away outboard and diffusing itself abroad. Nevertheless, the difference in total resistance produced by varying the point of its application, as shown by the foregoing figures, is most astounding. This reveals a vast amount of energy still remaining, for beneficial or for injurious application, in the echo, even after suffering the great losses to which I have referred—an amount which is quite inconsistent with the theory that at the outset it parted with half its energy to the bow wave. On the basis of that theory, indeed, by towing a line of vessels at such distance apart that the energy of the stern wave of a leading vessel would be suitably applied at the bow of a following vessel, and by thus economizing the energy of the stern wave as well, we should have the absurdity of being able to do away with probably all wave resistance, and perhaps even obtain a bonus of energy; and this in addition to creating, without expense, a vast frictional disturbance in the water by means of the lost energy of the echoes.

AN ECHO IS NOT NECESSARILY A WAVE.

A *current* is a transfer of substance and of energy. A *wave* is never, unless incidentally, a transfer of substance.

Some kinds of waves are transfers of energy, and some kinds are not. In the ordinary waves which are transfers of energy the particles usually take a circular or quasi-circular path, doing this in a vertical plane which extends in the direction of the transfer.

In waves which do not transfer energy the path is up and

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down in alternation. They cannot properly be called waves, except in obedience to established usage.

Where energy is transferred by a wave, the transfer is accompanied by the forward movement of an undulating outline. This marching outline makes a march of Form but not of Substance. Along the forward face of the wave the particles are rising. Along its rear face they are falling. At the crown they are moving onward. In the trough they are sweeping to the rear. When we watch a wave coming toward us, we shall see two things: one, that the particles are climbing; the other, that the form or display of surface is coming forward. After the wave has passed us, if we turn to watch it we shall see two things: one, that the particles are sinking; the other, that the form or display of surface is retreating from us.

Thus the wave may, on its front face, be regarded as clambering or climbing forward, and, on its rear face, as sinking or *tumbling* forward. If we say that, in its trough, it sweeps *backward*, we must add that this is only in order to surge forward again along the crown of the succeeding wave. Flitting onward, the ocean billow carries no substance with it. Instead of the substantial, it wafts an empty form or outline. But with the form there flits the inscrutable thing called Energy, which rides the Form like a phantom knight on a phantom horse, crying Forward! at every bound.

Among the energy-carrying kinds of waves belongs the scantling wave, marked D, of Fig. 1, four examples of which are shown on the starboard side of the vessel and five on the port. But the scantling wave, though energy-carrying, like the ocean waves, is not, like them, gregarious. No scantling wave marches in company with others, or keeps in touch with any. It paces by itself, without leader and and without follower, a solitary straggler, soon to sink in its tracks exhausted. D^4 is an undulation which got its start a few moments earlier, at a time when the bow was near to where the stern is now. The bow threw it off sideways and facing a little forward, and since that time its form and energy have been carried, as may be seen, to a considerable distance outboard and to a little distance ahead. These several and independ-

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ent undulations have none of them any concern whatever with the train of thwartship waves marked T. They enlisted for other reasons than those did, and they have deserted from the ship at the earliest instant.

The thwartship waves, on the contrary, are not of the energy-carrying kind. It is only in deference to usage that we can call them waves. It is only in respect to outline that their form is wavelike. Their form is wavelike in as far as it is an outline in which certain particles of the outline are seen high up and others are seen low down, and the rest are seen between high and low. The high parts of the outline sink and become the low parts, and the low parts rise and become the high parts. And they do this turn and turn about. But a wavering outline does not necessarily consist of particles which have acquired a forth-and-back as well as an up-and-down motion. A wavering outline is no test at all of wave-hood, and in the present case that outline is owing merely to the previous handling which the water particles have met with at the bow, and to the present handling which gravity gives them.

In Fig. 2, page 613, the particle which is at the point A^1 is at the very surface of the water, and will remain at the surface and next the ship's side till it leaves her at the stern, unless at the very outset it is entrapped in the scantling wave and perhaps gets rolled over. We may put a floating bottle, or a cork perhaps, at A^1, and thus mark for our purposes this special particle, since the cork or bottle will stick faithfully to the particle. By and by the cork and particle will be at the vessel's stern. This does not mean at all that they will have gone aft. It means exactly that the vessel's stern will have come forward and got to where the cork and particle are. The cork and particle will neither have come aft nor gone ahead meanwhile. They will only have been moving up and down. The waving line A^1, B^1, A^2, B^2, etc., etc., which we see described upon the ship's side, reaching from stem to stern, consists of this particle and innumerable others like it, all lying in the surface of the water, and all finding themselves at different places along the line.

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OCEAN WAVES AND TRANSVERSE WAVES CONTRASTED.

Let us compare the sea wave on the one hand, and the transverse wave system on the other hand, and try to see (*a*) in what respects they resemble each other, (*b*) in what respects they are different, and (*c*) how far their differences and their resemblances may bear upon the question of the source or sources of the energy of the bow wave. In making these comparisons let us keep the diagonal wave out of view altogether, save only to admit that some quantity of energy passes off in it sideways which we must entirely eliminate from the matter under consideration.

THE OCEAN WAVE DESCRIBED.

First let the ocean be perfectly smooth, and afterward let a gale spring up out of the west, and let the wind blow steadily from the west and raise a considerable sea, after which let the wind cease to blow. Then we shall have a series of very regular ocean waves rolling from west due east. Let the length of these waves from crest to crest be exactly the length found in one of William Froude's experiments,* viz: 115.8 feet, and let their speed be the speed which he fixes as due to an ocean wave of 115.8 feet in length, viz: 14.43 knots an hour.

Suppose we have two steamers which are capable of maintaining that speed precisely, even when they have something in tow. Out of thin plates of metal, riveted so as to make a plain surface, we cut the profile or sheer plan of a vessel whose length on the water line is equal to 115.8×4 feet, or 463.2 feet exactly. Since the metal is a mere thin sheet, the towing of it edgewise will raise no wave whatever. Now we get our two steamers into such position that each will head due east, being abreast of each other and some two hundred yards apart. We pass hawsers from the lowermast heads of one to the lowermast heads of the other, square across the interval; and to these hawsers we hang our profile or sheer plan of 463.3 feet in length. Of course the seamanship of this maneuver is not very good; but we are only

* Paper of March 23, 1877, Trans. Inst. Nav. Arch., had undoubtedly in mind by R. E. Froude, April 8, 1881, in the paper in which he gets, for the casting up of the bow wave, half the energy from the transverse waves which follow in its train.

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making an experiment. The steamers now steam due east at 14.43 knots an hour, towing the profile at that speed. The profile stands up straight like a ship, and the bottom of it reaches lower than the troughs of the waves, and the top of it reaches higher than their crests. We now have there, described upon the profile, the outline of a series of ocean waves, four in number, plain in sight, just as when a four-membered transverse system is described on a vessel's side. Since the profile is going exactly as fast as the waves, the outline of both crests and hollows remains steady and fast there, just as if it were glued to the metal. The profile, indeed, is moving east at 14.43 knots an hour, but the wave forms are moving east at just that speed, and so they keep up with the moving profile. To all intents and purposes this profile is a ship, save that it has no spread of the bows and has, in fact, no beam, and therefore it is not making any waves whatever. The ocean waves which accompany her have very nearly the look of the waves she would be making if she were a real ship and were going at just that speed, and the sea were perfectly smooth. There we see the series of ocean waves, with their crowns tucked up above the copper line, and their hollows tucked down below the copper line, exactly as if they were nailed to her, and exactly as if it were a series of transverse waves which she had kicked up in a perfectly smooth sea. Here we sketch roughly the profile ship, and the waves accompanying her, the latter all numbered for identification. We omit all diagonal waves, of course.

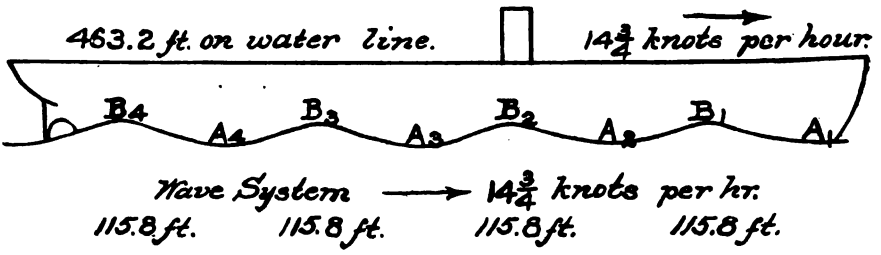

Fig. 2.

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The reason why the waves travel on with the profile and keep up with it, rolling through the water just as fast as the profile, is found in the circular motion which each particle of water is having. This circular motion wheels or trundles forward the form and energy (but not the substance) of the wave, in the same manner in which a hoop snake is said to get over the ground when it is excited. The swell or rise of the wave is simply the upper half of the circle in evidence, and the swale or trough is simply the lower half of it in evidence. The middle of the after face or surface of the wave shows where a particle in that part of its surface is sinking plumb. The middle of the forward face shows where a particle there is rising bolt upright. The crown shows where a particle occupying that position is rushing onward, and the trough shows where an occupant of that position is surging backward.

No water mass is moving onward. It is merely that water particles are moving *in* the circle, and that the circle, minus the water, is advancing. Now a mere circle is nothing but an empty form, and for an empty form to be transported forward without any particles being also transported forward, means merely that particle after particle (or, more literally, particle before particle) is undergoing a circular motion, and that after a particle has got the top of its promotion, and whilst it prepares to begin to sink, the particle next forward of it gets to the top of *its* promotion and prepares to sink like the other. The wave substance stays and wheels over and over; the wave form gallops on, and a certain wave energy rides the form, and the speed of the two is the swiftness with which the particles succeed each other in vaulting to the top of the wave. It is just as when children pass the "tag" or touch from one to another through a line of children, all of whom, however, may be standing fast. The "tag" is energy, and wave energy is substantially a strong tag or push along the line of particles. For instance, the water that lies beneath the form A^3 B^2 A^2, regarded as forming a portion of a real ocean system, will not advance further. But the highest point or crest B^2 will advance with the ship, because particles in advance of the particle which at this instant is at the crest, will at later

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instants climb successively up to the crest. Thus the slope B^2 A^2 will flit forward, and a moment later will be where at this moment the slope B^1 A^1 is, while the slope B^3 A^3 will meanwhile have flitted to just where the slope B^2 A^2 now is seen.

How the energy rides onward and with how powerful a stride, may be seen from the force with which the form B^1 A^1 knocks upward anything it may meet as the water in it rises, and from the force with which the on-surging water hurls itself upon whatever opposes it. Of course, and without shadow of a doubt, this wave will catch up any mass it finds in front of it, as, for example, the mass of peaceful and unsuspecting water just ahead of the point A^1, and will heave this up and dash it down again to the water bed. But if the water ahead *belongs to the company and trains with it already*, the wave energy will simply ride through it with cheer and with fresh encouragement.

THE TRANSVERSE WAVE MASQUERADES AS AN OCEAN WAVE.

(Expose the stub folder at the end of this paper.)

In my repertoire I have two figures like this Fig. 2. They are exactly alike, though I do not feel sure that either is very exact. One of them represents the thin sheet of metal in tow, and represents a following sea of mere rollers, without a breath of wind blowing, just as above described. The other is a picture, in elevation, of a real ship 463.2 feet long, of just the same profile or sheer plan as the preceding. She is making 14.43 knots an hour, and with her own steam, no wind blowing, and in a perfectly smooth sea. She is throwing up four transverse waves along her side, of just the length of the ocean waves in the other figure; the system looking as like the other system as two peas do to each other, except that there is now no "trough" just forward of the bow. By giving her bows (which, by the way, are unusually sharp) a certain peculiar shape I have so far eliminated the diagonal wave that it is no longer an embarrassment; some persons may doubt whether this is possible, yet no person who is thoroughly acquainted with model-making. Therefore I ask that Fig. 2 above may be suffered to stand for the outline of this real ship and of her transverse wave

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system, although the "trough" which is just forward of the bow ought not now to be there, and should be excluded from the representation.

And here at the bow, with the transverse system, is one of those places in which it is at first almost impossible that one should not fall into error, and is one of those places where his eyes will almost certainly mislead him. I think we have here an admirable example of that omnipresent wit-beswindling and that everlasting thimble-rig of the senses, which always and inevitably constitutes the matrix or reciprocally-concave mould for the casting of every true understanding of a matter; a matrix which indeed nourishes (yet also overlies and conceals) the truth as long as the truth is indeed in conception, but has not yet been fully brought forth to the light.

Because the transverse system has the form and look of an ocean-roller system; because it has the length and height and speed of such a system; because it keeps lock-step with the ship as the ship might keep step with the rollers if she should reach a true roller speed; and, above all, because the system seems to lay hold of the peaceful water just forward of the bow with the same contemptuous energy with which an ocean troop would lay hold of any still surface which it might find in front of it—therefore, and by virtue of this mere show or seeming, the transverse system is presumed by the eye to be inwardly *as* the ocean-roller system, and to possess all the bounding vigor of that system; whereas the simple fact is, the transverse system is the dullest and most spiritless wave-commotion that can possibly be produced. Instead of being a form that is careering magnificently onward, it only clambers up as best it may, in seeking to escape the bow which is perpetually flogging it on; in lieu of galloping forward it must ever be dragged at the heels; in fact, it will not march a step of the way, but stands now on one foot and now on the other, and simply marks time. We shall see this plainly enough.

DETECTION OF THE IMPOSTURE.

Closely observing Fig. 2, I take a pen in my left hand, with some particles of ink on the pen, and I put the point of the pen

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at A^1. I lay hold of the paper with my right hand. Then, all at the same time, I move the pen straight up and down with my left hand continually, and with the right I move the paper, with the ship's picture upon it, continually to the right and horizontally. As long as I do this, the motion of the pen, which is up and down continually, and the motion of the picture, which is horizontal to the right continually, will, between the two, leave a particle of ink at each successive point along the ship's side at the surface of the water, and will leave the particle of ink there at just the instant when, and at just the place where, in the up-and-down movement of the particle of water, each successive point in the picture of the ship's side will be reaching the particle. Thus the various particles of ink, successively left upon the paper, will describe the outline A^1, B^1, A^2, B^2, etc., etc., and will represent all those various particles of real water which lie in the surface alongside the vessel and which find themselves at various points in the line.

Now the straightforward energy of my right hand is playing the part of the ship's engines, and the energy of my left hand as it moves up and down merely, is playing the part of gravity which acts upon the ship-waves. The outline is an undulating one because it is the resultant of two motions, or rather of three motions, of which a pair are reciprocal. The ship on paper and the ship on sea are moving horizontally toward the right. The pen at A^1 and the particle of water at A^1 move straight upward. The combination of the two movements makes the up-slanting line A^1 B^1. The leftward or sternward component of this slant is not in the least traceable to the pen or to the particle in the sea. This component is the result of the motion of the paper in the picture or of the real ship on the water—in both cases a motion toward the right.

The down-slanting line B^1 A^2, composed of a straight-down element and a horizontal leftward element, is the result of the straight-down motion of the pen moved by my hand and of the particle in the sea moved by gravity, on the one hand, and of the horizontal motion of the paper ship and the real ship toward the right.

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The reason why the line is curved instead of tooth-shaped or jagged, albeit the components of it are perfectly straight and lie right-angled to each other, is as follows:—In moving the pen perpendicularly down and up I imitate as closely as possible the varying motion of gravity, according to which are caused the risings and the fallings of our particle and of its accompanying cork or bottle. At B^1 they are at a pause; the ship is moving horizontally to the right, and therefore the line, for a very short length of it, leads horizontally to the left. The cork and the particle then begin to fall, yet slowly at the very first, as everything does which gravity takes hold of. The ship continues her speed to the right; hence the line slants a little downward. The particles now are falling more rapidly, as gravity requires; therefore the line now begins to slant more downward. Until they are half way down they are falling faster and faster, so until then the line slants more and more downward. Presently, as they, or rather the particles underneath them, begin to fetch up on the water-bed, by reason of the reaction of other particles of water whose gravity has become disturbed by the fall, their downward motion becomes feebler, and therefore the line now has less and less of a vertical component. At last they fall no longer; the ship's motion to the right becomes the only motion, and the outline therefore a horizontal one leading due leftward or sternward. At this stage, the gravity of other particles of water which have been disturbed and forced upward by the fall of these, begins to tell upon the particle and the cork, and this gravity now forces them up again, slowly indeed at the outset; wherefore now the outline, though it does slant upward, slants only a little. Their upward motion begins to grow, while the ship's horizontal motion continues steady as before; thus the upward slant begins to be more pronounced. An instant later the upward motion begins to dwindle; and since the ship's horizontal motion remains undiminished, the line begins to grow toward the horizontal, and perfectly horizontal it becomes by the time the cork and particle reach B^2.

Thus, in short, the cork and particle to all appearances are

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making an up-hill and down-dale track toward the rear, and even continuing it far astern. The truth, however, is that they simply sink and rise, with a motion that is swiftest near the middle of each movement, and that fades away as they reach the top and bottom. The motion of the ship meanwhile being steady, and her form being rigid, the forward progress of each part of her side, where the wave outline is progressing also, is steady. The resultant of these two motions, the one a continued up-and-down motion of every particle of water, and the other a steady horizontal motion of every part of her side, is a see-saw (but rounded) outline of the water's surface composed of particles heaving up and down, each of them taking its regular turn in rising and in falling. The outline is a rounded or gently waving one instead of a jagged, because in their sinking and their climbing, and in their ceasing from each motion successively, their change as to motion is always gradual, and all this gives to the outline its easy curves instead of the sudden breaks which otherwise would distinguish it. In the outline their up-and-down motions are perfectly disguised by a merger into the concurrent horizontal movement of every spot on the ship's side with which the eye brings them into relation, as also by the circumstance that each particle in the surface whilst it is falling is in a position diagonally downward and abaft of another later-falling particle; abaft it, because it has always been abaft, and downward from it because it was beforehand in reaching the apex, and began sooner its fall and has longer been falling, and therefore has fallen farther; thus the after outline of the wave is a sinking and sternward-sloping outline. At the same time it is an outline that moves forward, because the apex B^1, situated at the critical point of the bow, is moving forward. In this manner, as to external appearance, the back of it appears like the back of an ocean wave. And for the same reasons, conversely applied, the front of it appears like the front of an ocean wave. But the two waves, ocean and transverse, are utterly unlike in character. The likeness of appearance is the sense-illusion of which I have spoken. The cognizance of their internal difference is a truth which underlies the fallacy of the senses.

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THE IMPOSITION ILLUSTRATED.

The process of the manufacture of the transverse train can be illustrated perfectly as follows: On glass or on transparent paper, describe in ink a wavy outline to represent the transverse system. On a separate sheet of ordinary paper draw a perpendicular line in ink. Place the glass or transparent paper so as to overlie the other, with the general lay of the wavy outline at right angles with the perpendicular line. The perpendicular line is visible through the transparent paper. Its intersection with the wavy outline is also visible.

Now move the transparent or wavy outline paper from left to right, holding still and fast the perpendicular-line paper which is beneath it. The wavy outline thus caused to progress to the right will represent the steady march of the transverse system as seen marked along the starboard side of a ship in motion. The up-and-down line, on the other hand, is the line of the force of gravity acting upon each particle of water, whether downward, in obedience to gravity acting directly upon *it*, or upward in rebound from other particles whose gravity has been disturbed by its fall. The point of intersection between the wavy line and the up and-down one marks the position of any surface particle. Whilst we are moving the transparent paper sideways, if we follow this point of intersection as it travels up and down the perpendicular line, and sidles aft along the wavy line, we see represented the total history of the various movements of any and every particle in the surface. For the particles there are all alike, and behave alike, each taking its turn in a really merely up-and-down movement, whilst still maintaining its part in forming the total wavy surface.

DOINGS BENEATH THE SURFACE.

It is unnecessary to consider the motion of particles in lower strata, since these merely constitute corresponding layers in deeper water, and behave almost the same as the uppermost layer. Only in general it is to be remembered that, roughly speaking, whilst a lot of particles are sinking into the forward part of the trough, more room is being made abaft in the water

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bed, from the after part of the trough, by another lot of particles situated next abaft the former lot. This second or after lot is rising by virtue of the almost-just-now disturbed, and absolutely just-now reasserted, gravity of other water into which it had fallen an instant earlier; and this after or more sternward lot is also *helped* to rise by a certain further impulse (let us examine it later) which comes, transmitted through other water, from the energy developed by the first lot in its fall. This helping energy takes effect in a sternward, and not in a bow-ward direction, for the reason that next to it, between it and the bow, and on a higher plane, there is falling at this instant, as we know, a third lot of particles, and the energy of *that* lot has a downward drive, against which the energy of the middle lot will not make head, but will rather go toward the lot which lies abaft, where already there is a decided yielding.

THE ENERGY COUNTERMARCHES QUASI-STERNWARD.

Thus it may be said without error that there is a continuous current of energy passing down and up, and withal sternward, with countermarching in vertical plane, along successive vertical sections of falling and rising particles; which current of energy consists not only of that energy which is inherent in the substances there in motion, but which, over and above this, consists of an energy laid on in fresh increments from forward, from fresh waves generated ahead, and transmitted sternward continuously *through* the moving substances, and, as it were, outstripping their several alternate motions. We say "sternward," but this, for the most part, is relatively speaking: the principal thing is to recognize that in any mass of these vibrating particles, the energy already acquired by them and which is being lost by friction, etc., gets steadily reinforced by a supply had from particles found next bow-ward which are in younger and more vigorous vibration.

Thus it appears that while the waning energy of the ocean wave which earlier we were considering, gets reinforcement from the wave behind it, the waning energy of a transverse ship-wave, on the contrary, is reinforced from the wave in front of it. This last is easily seen to be the case from the circumstance that when

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first noticeable, when the ship is just beginning to move, *it is the bow wave that is created first of all.* Not until an instant later are other waves seen abaft it; from this circumstance it becomes evident that the waves abaft it are only its echoes or reverberations; that is to say, are echoes and reverberations of bow-wave masses thrown up in steady procession during instants prior to the instant at which was thrown up the bow wave at this instant visible in the van.

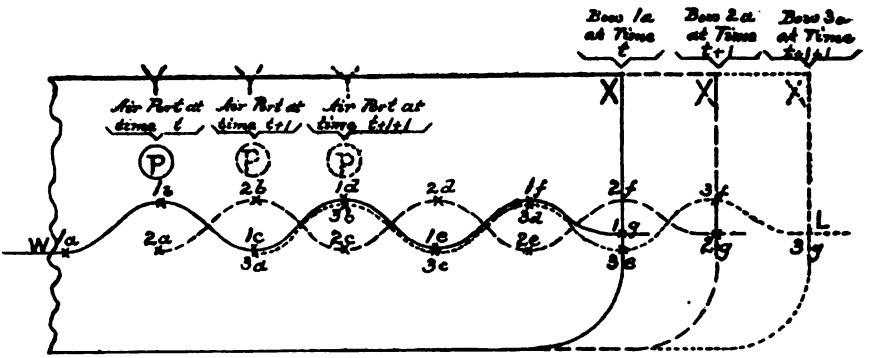

Fig. 3.

But the process can be made plainer by help of a diagram.

In Fig. 3 let YX be the forward portion of a vessel moving through the water. In this figure I magnify greatly the height of the waves, although such waves can really be produced by appropriate lines in the shaping of the vessel, and by moving her at the proper speed. But since the constitution of all transverse ship-waves is the same, the only effect of exaggerating the height of the waves is to make the details of wave-making somewhat plainer to the eye.

In this figure we see full lines, broken lines and dot lines.

The full ones stand for the vessel and her position at a certain instant which we will call the instant *t;* they stand also for the surface of the water along her side as seen at the same instant.

The broken ones stand for the same vessel when she has reached a spot half a wave's length farther forward, which spot

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she reaches at the instant $t + 1$; they stand also for the water as it appears at this instant.

The dot lines stand for the same vessel when she has reached a spot which is a wave's length ahead of the first spot; this spot she reaches at the time $t + 1 + 1$; they also stand for the water in the position in which it finds itself at this latest instant.

In order to avoid confusion, we suppress entirely the scantling or diagonal wave. This suppression does not affect the character of the transverse waves; for that matter, it is easy to shape a model so that her diagonal wave will at least be imperceptible. The waves, as they have been called, or the "wavings" as perhaps they ought to be called, march steadily with the ship; and the outline of each of them stays in its own place just as if the whole outline had been triced up to bolts, and lashed down to bolts, driven into the ship's side at the crowns and troughs of the waves.

HOW THE WAVINGS MARCH WITH THE SHIP.

No. 2 of the wave system at the time t,—No. 2 consists of the particles which lie below the outline $1a1b1c$, being particles lying between that outline and deep water—has now its crown at $1b$, or directly under the air-port P, which is beneath the inscription, "Air-port at time t."

At an instant later, viz., at $t + 1$, the vessel will have moved half a wave's length forward, and the *broken* perpendicular line will show the new location of her stem; and when she shall have moved another half wave's length, which will happen at $t + 1 + 1$, the new location of her stem will be indicated by the perpendicular dot line seen further ahead.*

This ship has but one air-port. Its location at the instant t may be seen directly under the words, "Air-port at time t." At $t + 1$ it is under the words, "Air-port at time $t + 1$," and at $t + 1 + 1$, it is under the words, "Air-port at the time $t + 1 + 1$."

Each "waving," as we may call the water-elevation, advances its position exactly as fast as the various parts of the ship advance theirs. At the instant t, the waving which at that instant

* Expose the stub folder at the end of this paper.

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is the third of the series, is found with its surface particles forming the full outline *1a1b1c*; and at $t + 1$, the waving which at that instant is the third of the freshly-existing series, is found with its surface particles forming the broken outline *2a2b2c*. At $t + 1 + 1$, the waving which at that instant is the third of the still more newly-presented series, is found with its surface particles forming the dot-outline *3a3b3c*.

At $t + 1 + 1$, the ship having advanced a whole waving's length, the position of the outline of the third waving, viz: *3a3b3c*, is identical with the position of the outline *1c1d1e* of the *second* waving of the system exhibited by her at two instants ago when she was farther to the rear; the two wavings themselves are identical and take place in one and the same set of particles. And at this present moment the outline of the second waving (as the train now stands), viz: *3c3d3e*, is identical with the outline *1e1f1g* of the bow wave in the system as it stood two instants ago, viz: at the time t, and the two wavings themselves are identical, except as to the front half (*1f1g*) of the outline *1e1f1g*, in respect which we must note that when the bow enters the undisturbed water ahead it finds this water at the normal level instead of the lower level on which the troughs are found.

It will happen, then, that in any series the waving which stands third in it will have the same outline, and will exist in the same particles of water, as the waving which stood second in the next earlier series. The same will be the case between the waving which stands second in any series and that which stood foremost in the earlier series, except that the foremost waving, being the bow wave, carries no trough ahead of it. For ahead of it the water is merely at normal level, which is half a wave height higher than a trough.

In the first or bow wave, *3e3f3g*, the particles lying plumb beneath *3e3f*, in falling perpendicularly, throw some of their energy into particles lying in the water bed and disturb the gravity of those particles. When the gravity of the latter recovers itself, the falling particles just mentioned are thereby hoisted up again and are found under *3d3e*, becoming the front

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half of the second wave in the series next later created, of which later-created series the leading member, as we see, will rear itself one wave length farther ahead in the line. The rest of the energy of the falling particles lying beneath *3e3f* is played by them upon or into the particles lying beneath *3d3e* abaft them, and the particles under *3d3e* are helped perpendicularly up by the perpendicular fall of the former. This is done by the reasserted gravity of still other particles which have been disturbed by the falling particles lying beneath *3e3f*. The particles *3c3d3e*, whose front division is now being encouraged upward, are really no other than our old friend the bow wave who was holding his head still higher just two instants earlier, when the ship was a wave length farther aft and he was the leading wave of all.

WHY THE WAVINGS MARCH WITH THE SHIP.

The undulation marches on in the following fashion :

As the ship moves ahead, the outline *1a1b* (constituting the rear face of the waving *1a1b1c*) has all its particles falling perpendicularly; and the outline *1b1c*, constituting the *front* face of the waving, has all its particles rising perpendicularly. The point *1b* marked upon the ship is the *critical point*, by which is meant that at just this point in the ship's side the particles in the front face of the wave successively cease to be rising, and thereby cease to be constituting the front face, as *1b1c*, but begin to fall and thereby begin to constitute the rear face, as *1b1a*. By this constant falling of the particles which are at the rear, and constant rising of the particles which are at the front, and constant and ship-accompanying movement of the point where a particle ceases to belong to the front and begins to belong to the rear face, it comes about that both the front and rear outlines travel steadily on with the ship. This travel of outline will happen just as it happens with an undulation of any long rope of convenient thickness, held with tension neither taut nor slack, between two persons. If the person in the rear gives the rope a simple jerk downward, an outline of wave depression will travel forward the whole length of the rope. If, however, he swiftly follows the down jerk with an up jerk, a wave outline of depres-

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sion, conjoined with a following elevation, will travel forward; and if he continues to jerk the end up and down, the rope will show a series of wave outlines of depression and elevation.

But, except as to the mere process of wave marching, the rope illustration is misleading; for the rope gets its outline-producing energy applied at the point from which the march advances, and the energy developed progresses with and along the march. With the transverse series of waves, on the contrary, the outline-producing energy is applied steadily *at the van*, and the troopers catch up from the van the undulation, and they maintain it by virtue of gravity, alternately active and reactive, the column meanwhile marching and keeping exact distance.

A TEST OF THE DRIFT OF ENERGY.

On one side of the top of a bucket we fasten a special lip, contrived for pouring water out of it in an easy flow. Let the edge of this lip be straight, and let it be tangent to the circumference of the top, so that the water in being poured will fall straight-edged, as if over a mill dam. We take a trough and nearly fill it with water, and we fill the bucket also. Holding the bucket above the trough and close down to it, we walk along and pour out water into the trough, letting it merely fall as we advance. Following the fall, and advancing as we advance, we shall see an undulation, and in an instant we shall see more undulations behind that one, all marching along behind the bucket, and keeping due distance. The foremost undulation of the train is the rebound of the outpoured water, or—just as good—of water displaced by it; and the second undulation is the first rebound of the first undulation. Now the water in coming out of the bucket and falling as it comes, behaves exactly like the falling water in the after half of the transverse bow wave. The undulations which the bucket trails along behind it are exactly in the condition of those members of the transverse train which follow the bow wave. Those members have no more part in raising the bow wave than these undulations have had in getting the water originally into the bucket.

The ship has no bucket forward there, and no reservoir of

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raised water. She raises the water steadily as she goes, and she steadily drops it again at the critical point of the bow. Her process of wave-making without any reservoir is essentially the same as was our process with a reservoir.

A BETTER TEST AS TO THE DRIFT OF ENERGY.

For that matter, instead of a bucket, take a flat-based, perpendicular-sided, round-topped piece of wood, shaped like the uppermost third of a steamer's paddle box, and halve it by a transverse perpendicular cut from crown to base. One of the halves we drag through the water, near the surface, rounded side upward and forward, letting the water pile up in front and over the crown and fall abaft the crown, and create a train of waves that follows along behind.

BUT THE BEST TEST IS THE FACT ITSELF.

It may seem as if the work thus done were not quite analogous to the work of the ship's bow in producing the transverse bow wave, because the wave is begotten *above* the rude model instead of along its side. Therefore let us turn the plane of the model ninety degrees sideways, and have the round part at the side instead of at top. If we force this through the water, the round part foremost, we shall be making waves upon at least one side of it. They will be like the waves made by this same piece of wood in its former position, only they will be of water which has been lifted by being caught between the rounded surface and other water lying *to one side*, whereas in the other case they were of water which had been lifted by being caught between the rounded surface and other water lying *ahead*. In both cases alike it is evident that the fall of the water from the wave height to which it has been raised is an event which is subsequent to the raising and cannot aid the raising, but will result in a consequent rebounding or echo.

SEEK CHARACTER WITHIN AND NOT ON THE OUTSIDE.

The essential difference, then, between the transverse system and the ocean system—the latter system being taken as consisting of rollers running in a perfect calm, yet advancing (let us suppose it) into undisturbed water—is as follows:

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While the two are substantially alike in profile, and alike in the onward movement of profile; alike also in adding to their length at the van of the column only; alike moreover in effecting this addition by means of energy applied at the van; alike, in short, as to every feature which the eye can note—or can note in water on which no objects are floating—while alike in all these outward respects, they are wholly opposite in all inward and essential ones. Instead of transmitting, *from behind*, the energy for maintaining and carrying forward the system, passing the energy through the system, as the ocean wave does always, the transverse system applies *at the front* a fresh energy created at the front; and then, leaving the new wave and its energy to dance up and down in the spot where created, it marches on and repeats the process with a fresh mass of water and a freshly created energy.

PROFESSOR LAMB'S SCHOLIUM.

The doctrine of Professor Lamb appears to call for further discussion.

It relates to the case where the transverse system consists of a bow crest and a stern crest, with a solitary depression between them; and his suggestion is that in this case there is really no loss of energy from wave making.

Here the rising of the echo of the bow wave becomes coincident with the rising of the stern wave. The rising of any stern wave whatsoever means the diversion, into a useless hoisting of water there, of energy which should have been applied in pressure upon the up-and-aft-and-outboard-sloping immersed skin of the afterbody, in order to twinge the vessel with a forward pressure. In Professor Lamb's, case, however, the bow wave echo makes confederation with this insurgent water. Thereby the echo not merely increases the waste by its own store of energy, but also applies that energy in opposition to whatever beneficent forces may be operating at the stern.

In order to restore to the ship the energy which the ship has put into the bow wave, the echo of this wave ought to bring its particles to apply the momentum of their up-motion against the rising bottom and convergent sides of the afterbody, along the

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run, at that place of hollow, half-hearted urgency and insistence on the part of the now confluent superficial streams, where as yet they are not willing to flow promptly inboard as they ought, but negligently leave a depression there instead of establishing a positive and helpful pressure. In Professor Lamb's stern-wave case, on the contrary, the treacherous echo does, in fact, along the run, in the region of depression, just before it confederates with the stern wave proper, set the energy of its now down-moving particles at work, destroying, as far as they are able to do, the good effects of the streams of lower strata which, ever faithful to their labor, and impressed (through the instrumentality of surrounding water) with the gravity of the occasion, are thrusting upward with all their might against the rising bottom of the afterbody.

The case in which there is no loss of energy by a transverse bow wave, save loss by internal friction and external dispersion of itself and echo, is where the up-motion of the particles of the echo takes place in the spot of *subsidence in front of the stern wave*, and fills up all depression there. For it is the reaction from this depression that causes the elevation of the stern wave. If the bow-wave echo removes the depression, the water preserves an even bearing, and no stern wave whatever is created. And if no stern wave, it means that the immersed surface of the afterbody is receiving as much bow-ward pressing energy from the stern water, as the forebody is receiving of sternward-pressing energy from the bow water; excepting, however, all losses by the diverging wave and by friction in casting up the bow wave, and by internal friction and outboard dispersion in the echo during the time it takes the stern to advance to the spot where the previous bow wave is performing a reverberation. Perhaps a perfect level at the stern, and not a rise of water there, is what Professor Lamb has really in mind, although he speaks of an "elevation of the water at *each* of the former points," *i. e.*, at the bow and the stern, as an elevation which "causes no loss of energy." For it is clear that with these two elevations we must have two distinct and complete losses; while in a single bow wave with absence of stern wave we have no loss (save as above

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excepted), because the energy expended in hoisting water against the forebody is returned to the ship by the later thrust of the echo of the same hoisted water, a thrust which presses against the rising and narrowing under-surface of the afterbody. But if Professor Lamb's contention were literally true, it would be *without any expenditure of energy* that the ship would be performing the work of raising both these elevations as well as the resulting echoes astern.

THE CONDITIONS AT THE TWO ENDS ARE OPPOSITE BUT SYMMETRICAL.

Concerning the stern wave it may rightly be said that all, or nearly all, the things which are true of the bow wave are true of it, yet with reversedly symmetrical parallelism. Many matters relating to the one wave which at the first may appear inexplicable, become quite simple when illustrated by things observable in the other. If we light upon a mysterious phenomenon at one end of the ship it behooves us to turn to the other end, where we shall probably find the explanation. It seems, indeed, as if the inevitable bewildering and the chronic sense-illusion which attach to all sensuous phenomena, could, in this field at least, be themselves eluded, and as if, by means of this interchange the habitual sense-inversion were in fact converted into a straightforward and normal impression.

A SIMPLE PHENOMENON.

A phenomenon to which no reference has thus far been made may perhaps confuse the experimenter, and may seem at first to militate against some of the foregoing observations.

If, during the propagation of a powerful transverse train, the model be stopped upon the instant, the train will still move forward. In this occurrence the beginner will naturally (and in conformity with the customary sense-illusion), suppose he beholds a confirmation of the theory that the transverse wave gets a part of its energy from the train behind it.

The cause of this continued on-rush is as follows: The water in front of and beside the bow can by no means be elevated against the force of gravity, except by a pushing of its particles forward; in the course of which forward-pushing it happens that

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certain underlying particles underrun certain other particles which belong to the more nearly superficial strata, and in which those superficial particles ride the deeper lying ones. Thence it comes about that whilst in the deeper strata there exists a general leisurely forward and outboard movement of lower strata pressed forward and outboard by the vessel's progress—by forward I mean in the direction of the vessel's progress—there is taking place in the upper strata a sudden forward and outboard transportation of the more superficial water which the bow is ever encountering and crowding very brusquely into those directions.

CAUSE OF THE STERNWARD DEFLECTION OF THE TRANSVERSE TROOPERS.

It may therefore be rightly said that the transverse train consists of water which possesses a degree of forward motion—forward, relatively to the outboard quiet water. The continual forward shove of the spreading contour of the bows produces a forward set along the vessel's side. Here, too, seems to be found the proper explanation of the observable sternward deflection of each member of the transverse system at its outboard end. This deflection William Froude sought to explain on the ground that "when a wave is entering undisturbed water its progress is a little retarded, and it has to deflect itself into an oblique position so that its oblique progress shall enable it exactly to keep pace with the ship." (*Parallel Middlebody*, Trans. I. N. A., 1877.) This is true in a way, yet not in the way which I think William Froude had in mind. The "progress" he was thinking of was to be a progress *qua* wave, a progress of motion and not a transportation of substance. The progress which really exists there and which gives the members of the transverse system an oblique deflection is a progress *qua* water, a forward transportation of the particles. The inboard portion of the wave or reverberation is situated in a portion of the forward-moving current which has a stronger forward set than has the more outboard portion. These reverberations or echoes do not revolve or roll forward; they merely dance up and down; and the lagging of their outboard ends is simply the result of outboard spread or extension

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(effected through friction between original echo water and the next outboard water) of the motion of reverberation, communicating itself to water possessing less forward impetus than is possessed by the water in which the reverberation first began.

ULTIMATE STRETCHING OF THE ECHOES.

Now this onward motion of the water in which the transverse waves, or rather wavings, are in operation, is one which it will retain for a considerable time, and which in disappearing will be lost only by degrees, viz: in proportion as it gets farther and farther aft and farther and farther astern. The loss of this forward set or push will result in a slight lengthening of the echoes, measured from hollow to hollow, as they reach farther and farther astern. This lengthening will in part, however, be the result of a different cause, viz: the gradual dissipation, sternward no less than transversely, of a slight amount of quasi-potential energy existing in the system, and in part it will be the result of a third cause which it is not necessary to discuss in this connection.

If the water movements have now been correctly described, it follows that the formulas of the commentators are in error, and that the ship's engines are obliged to furnish the whole of the energy which enters into and throws up the bow wave. All of this is sheer waste save so much as can be recovered along the afterbody or at the stern.

THE MATTER IS A PRACTICAL ONE.

Respecting the bow wave and its formation, there are several facts which bear specially upon the problems of ship design for speed and for burden; and which it may therefore be interesting to consider at a future time. The first or opening measure to be taken in all real reformation is necessarily in the nature of pruning and purgation. Healthy growth is, of course, a subsequent process.

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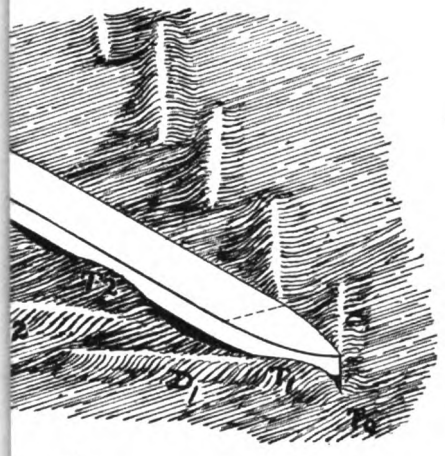

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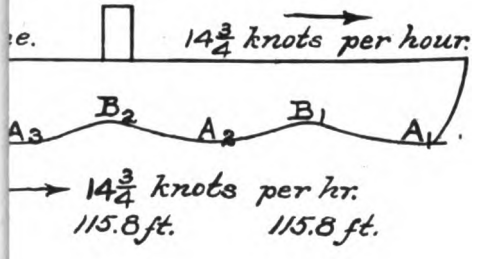

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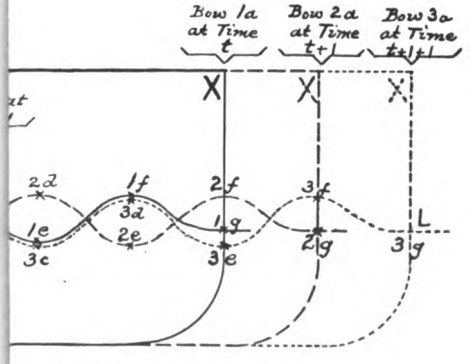

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SOME EXPERIMENTS HAVING REFERENCE TO THE DURABILITY OF WATER-TUBE BOILERS.*

By A. F. Yarrow.

Feeling sure that anything which may tend to increase the durability of water-tube boilers will interest the members of our Institution, I have much pleasure in laying before you the results of some experiments which we have recently carried out with a view to ascertain the comparative merits of nickel-steel tubes and tubes of mild steel, such as have hitherto been used in water-tube boilers. The nickel-steel to which this paper refers is an alloy, having from 20 to 25 per cent. of nickel, and in these experiments we have tried to repeat as nearly as possible the worst conditions as regards wear and tear to which tubes in water-tube boilers are subjected.

The deterioration of the tubes is probably owing (1) to the action of acids in the water, due to grease, which in spite of every precaution, finds its way to the boiler; (2) to the tubes becoming overheated and oxidizing on the outside, through contact with the hot gases when passing from the furnace to the uptake; (3) to the action of the steam, which, if superheated, decomposes, causing deterioration on the inside of the tubes. The last two conditions occur when the tubes, from defective circulation, shortness of water or from the collection of scale, become overheated.

Table I records what we have termed the "corrosion test." It will be seen that the piece of nickel-steel tube A was compared with the piece of mild-steel tube B, the original weights of which were 190 and 186 grammes respectively. Both the tubes were immersed in the same dilute solution of hydrochloric acid for various periods, as indicated. The duration of the tests varied, as shown, from 21 to 168 hours, making a total number

* Read at the July meeting of the Institution of Naval Architects. [In reprinting this article several figures have been omitted.—Ed.]

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of hours for all the trials of 533. The ultimate loss of weight in the nickel-steel tube was 5 grammes, and in the mild-steel tube, 98 grammes. It will be seen that the original weights of the two specimens in this case did not accurately agree; but in the second trial, E and F, the tubes were of the same original weight, namely, 188 grammes each. The ultimate loss of weight was found to be 7 grammes with the nickel-steel tube E, and 100 grammes with the mild-steel tube F.

TABLE I.—CORROSION TEST.—TO ASCERTAIN THE EFFECT OF ACID ON NICKEL-STEEL AND MILD-STEEL TUBES.

Marks and material.	Original weight. Grammes.	Two parts water, one part hydrochloric acid.									Total loss in weight during 533 hours.
		Duration of immersion in hours.									
		21	64	44	92	168	72	24	24	24	
		Weight in grammes at end of each period.									
Nickel-steel, A	190	190	189	189	188	186	186	185	185	185	5
Mild steel, B	186	184	173	166	140	101	98	94	91	88	98
Nickel-steel, E	188	188	187	187	186	183	182	181	181	181	7
Mild steel, F	188	187	173	162	137	112	95	92	90	88	100

The upshot of the above tests, it will be seen, is that the loss of weight in the first series of tests of the nickel-steel tube amounted to 5 grammes, being 2.63 per cent., and in the mild-steel tube to 98 grammes, being 52.68 per cent. In the second series of experiments the loss in weight of the nickel-steel tube was 7 grammes, being 3.72 per cent., and the mild-steel tube 100 grammes, being 53.19 per cent. The average loss of weight in the mild-steel tube was therefore sixteen and one-half times that what it was in the nickel-steel tube.

It may be contended that the relative corrosion of the two specimens when using dilute hydrochloric acid does not corre-

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spond with what it would be with such acids as are present in boilers under working conditions, but it is not unreasonable to suppose that it may serve as a guide.

TABLE II.—FIRE TEST.—TO ASCERTAIN THE EFFECT OF FIRE ON NICKEL-STEEL AND MILD-STEEL TUBES.

Marks and material.		Original.	Heated blood red for thirty minutes and allowed to cool.	Heated bright red and cooled in water.	Scale removed.	Heated straw color for one hour and allowed to cool.	Tubes partly flattened to remove scale.	Heated straw color for one hour and allowed to cool. Scale removed.	Heated straw color for one hour and allowed to cool. Scale removed.	Heated one hour, straw color, and allowed to cool.	Scale removed.	Total loss in weight.
Nickel-steel, C.....	Wt. in grammes.	192	192	190	190	171	170	159	151	145	145	47
Mild steel, D.....		185	184	183	180	130	120	94	68	42	40	145
Nickel-steel, S.....		188	188	186	186	172	172	153	142	139	136	52
Mild steel, H.....		188	188	186	184	147	145	89	58	51	45	143

We will now turn to Table II, which records what we have termed the "fire test." This was conducted in the following way: Two tubes were placed side by side in a small brick furnace, where they were heated to the same extent, and in every way were practically under the same conditions. The loss of weight of each tube due to oxidization after they had been in a very heated state is indicated by the weights given. It will be seen that the original weight of the nickel-steel tube C was 192 grammes and of the mild-steel tube D was 185 grammes. The total loss of weight in this series of tests was, in the case of the nickel-steel tube, 47 grammes, or 24.47 per cent., and of the mild-steel tube, 145 grammes, or 78.37 per cent. In this case also the original weights of the two pieces of tube were not exactly the same, and we therefore repeated the experiment, as shown by G and H, in which the weights of the two tubes were

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identical, namely, 188 grammes, and the loss of weight was found in the nickel-steel tube to be 52 grammes, or 27.66 per cent., and of the mild-steel tube, 143 grammes, or 76.06 per cent. The average loss of weight in the mild-steel tube was therefore 2.9 times what it was in the nickel-steel tube.

These results were submitted to Sir John Durston, and he pointed out that the experiments did not accurately conform to all the conditions under which boilers are worked, inasmuch as the tubes, in the case of a boiler when the heating surfaces are not in close contact with the water inside, are subject not only to the action of the gases on the outside, but to that of the superheated steam in the inside. The correctness of this view is unquestionable, and we consequently tested two tubes having a length of 1 foot 8⅝ inches by a diameter of 1 inch, outside by 14 L.S.G. This experiment we termed the "superheated steam test." The experiment was carried on in the following manner: Two tubes, one of nickel-steel and the other of mild steel, were placed side by side in a small brick furnace; at one end of each tube steam was supplied at 60 pounds pressure, it being allowed to issue slowly from the opposite end of each tube, thus ensuring the steam being highly superheated. The original weight of each tube was 612 grammes. After the experiment had proceeded ten hours, it was stopped, as the mild-steel tube gave out, steam issuing from the defective place. The loss of weight in the case of the nickel-steel tube was 12.7 grammes, and in that of the mild-steel tube 85.2 grammes. Deterioration in this case is due partly to the action of the steam inside the tube and partly to that of the gases outside.

The loss of weight of a boiler tube from deterioration at the commencement of its life being much less rapid than towards the end of its life, the loss of weight cannot be considered as a quantitative guide for durability, and we continued the superheated steam test as follows: After the mild-steel tube had burnt through and allowed the steam to escape, we replaced it by another similar mild-steel tube corresponding to what would be done in retubing a boiler. The experiment was then continued, and it was found this second mild-steel tube gave

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way, and the steam burst through after eight hours, the nickel-steel tube still remaining intact. We then substituted this burnt mild-steel tube by another, and we found that after three hours the nickel-steel tube gave out. Every two hours during these experiments the position of the tubes was changed about, not only end for end, but side for side, so as to ensure that both tubes were subjected to the same conditions.

It will be seen from this that the durability of the nickel-steel tube corresponded to twenty-one hours, and the mean durability of the first two mild-steel tubes to nine hours. I think, therefore, that there is a probability that from this cause of deterioration a boiler would require to be retubed two-and-one-third times as often with mild-steel tubes as it would with nickel-steel tubes.

In the last experiment the tubes were heated to a bright red, and as it would be unwise to come to any conclusion based upon a single set of experiments, we repeated it in precisely the same manner, with the exception that the tubes were in this further test only heated up to a very dark red. They were, in this trial, 3 feet 6 inches in length. The result was similar in character to that obtained when the tubes were heated to a bright red, the only difference being that the trial lasted considerably longer, as the deterioration was not so rapid on account of the low temperature. The greater durability of the nickel-steel tube, as compared with those of mild steel, was fully confirmed. The nickel-steel tube lasted 2.8 times as long as one mild-steel tube, and twice as long as the other mild-steel tube. Both ends of the tubes were fitted with copper expansion pipes, the object of which was to allow the tubes to expand and contract freely.

It is a well-known fact that a mild-steel plate, or a mild-steel tube, when heated and cooled, becomes permanently reduced in length, and this fact must be borne in mind in boiler design, because frequent variations in temperature take place in a boiler, owing to the opening and closing of the fire door, and the constant varying intensity of the combustion. This permanent contraction during the life of a tube varies according to circum-

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stances, but we thought it well to have some record of its extent when subject to the conditions under which the tubes were placed in this superheated steam test. During the life of one mild-steel tube, 3 feet 6 inches in length, heated twenty-one times to a dull red heat for periods of two hours' duration each, steam passing through the tube at a pressure of sixty pounds, its length was permanently reduced $\frac{56}{64}$ inch. The nickel-steel tube of the same length subject to the same conditions increased $\frac{14}{64}$ inch. The lengths were recorded every two hours, and the extent and periods at which the increase and reduction of length took place were clearly shown. Although, as I have said, it is a well-known fact that a mild-steel tube will diminish under these conditions, the extent to which this takes place is not perhaps generally known.

In the foregoing experiments the tubes were ungalvanized. Had the mild-steel tubes been galvanized there would have been a small addition to their durability, the extent of which is a matter of doubt.

We then made some trials with a view to ascertain the relative expansion by heat of the two materials. Two tubes were taken, 22 inches long, 1 inch in diameter, No. 16 L.S.G. They were inserted in a large tube and heated gradually up to a dull red up to about three-fifths of their length. The tubes were fastened together at one end and projected freely and independently beyond the furnace at the other. A record of expansion of each of the tubes was made by means of a trammel, and their expansion accurately determined. It was found that the expansion of the nickel-steel tube was considerably greater than that of the mild-steel tube. The process of heating up occupied 330 seconds, and it was found that the relative expansion was as 3 to 4, the nickel-steel expanding the most. The object of this experiment was to ascertain whether there was sufficient difference in the expansion and contraction of the two materials to cause trouble when nickel-steel tubes are placed within a group of mild-steel tubes. The result points to possible risk in this direction, and should it be desired to place nickel-

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FIG. A.

FIG. B.

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steel tubes in those parts of the boiler where deterioration proceeds with the greatest rapidity, and mild-steel tubes elsewhere, this variation of expansion should be borne in mind. I am not prepared to say that it is a source of risk; but it is one of those practical points which must not be overlooked.

To illustrate the suitability of nickel-steel from a mechanical point of view, I have brought a few specimens, see Fig. A, Nos. 1 to 6, to illustrate its ductility, which is almost equal to that obtainable with mild steel. I would submit that the ductility of these samples is amply sufficient for all practical purposes. Nickel-steel is considerably tougher in working than mild steel; it involves more labor, and causes greater wear and tear of the tools employed in expanding the bellmouthing, to which latter operation we have always attached the highest importance. The ductility does not seem to be impaired by sudden changes of temperature, as shown by specimens Nos. 7 and 8, Fig. B, these specimens having been bent after being repeatedly heated and chilled. The tools upon which our tests have been made were supplied, some by Messrs. Firth and some by Messrs. Krupp.

As regards cost, sufficient has not yet been done to know what the probable ultimate price will be, but, doubtless, it will be reduced from what it now is, if tubes of this alloy are introduced. Even at the present stage, judging from the experiments described, it is not unreasonable to expect that the longer life of the nickel-steel will prove fully proportionate to its higher price, if the cost of the more frequent replacing of the mild-steel tubes is taken into account; and, if this surmise is correct, clearly a decided gain would be obtained by the greater trustworthiness of boilers with nickel-steel tubes, and by avoiding the frequent loss of time involved in retubing operations, during which period the boiler is laid up.

I would observe that we have tried experiments as to the comparative durability of nickel-steel having small percentages of nickel, say up to 5 per cent., and have found that a very slight increase of durability is obtained by such alloys, but not sufficient to render them of any practical value for boiler tubes.

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SUMMARY.

From the foregoing experiments I think it not unreasonable to assume that nickel-steel, 20 per cent. to 25 per cent., boiler tubes will have, as regards acid corrosion, a vastly longer life than those of mild steel, and, as regards the deterioration from the action of heated gases or steam, at least twice the durability of mild steel. Before concluding I would like to mention that these experiments have been carried out in consequence of our attention having been called to the possible advantages of nickel-steel tubes by Mr. Andreæ, the engineer-in-chief of the Dutch Navy.

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THE LOGICAL ARRANGEMENT OF THE MOTIVE POWER OF WARSHIPS.*

By Rear Admiral George W. Melville, Engineer-in-Chief, U. S. Navy.

[While this paper was read in March last, and has been widely reprinted, either in whole or in part, both in this country and abroad, the Journal deems it of such importance that it takes this occasion to record it in full in its pages, being now able to include the complete discussion as well as the reply to the same by the author, Rear Admiral Melville. To this reply attention is particularly invited.—Ed.]

In the preparation of a set of tables showing the power required to drive a vessel of a given displacement at a given speed, data have been used which were gathered from the results of about two hundred trials of nearly as many ships. From this set of tables there was developed the remarkable fact that the propulsive efficiency of vessels with three screws is, in almost every case, above that of ships of approximately the same size, speed and general lines, but fitted with only two sets of engines. Attention has heretofore been drawn to the remarkable performance of the U. S. cruisers *Columbia* and *Minneapolis* on their trials. Recently, as the number of high-speed ships has increased so greatly, it has been very interesting to those who were responsible for the plans of the machinery of these cruisers to note how well they have maintained their position in the front rank of all naval vessels. These five-year-old ships, ten years old in design, are still among the most economical vessels in the world's navies as far as propulsive efficiency goes.

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* Read at the Fortieth Session of the Institution of Naval Architects, March 23, 1899; the Right Hon. the Earl of Hopetoun, G.C.M.G., President, in the Chair.

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There are many reasons for the superiority of the *Columbia* and *Minneapolis* over other vessels of the U. S. Navy, built at about the same time. The stream lines of these ships are remarkably easy, and the resistance is low, these factors giving—it is claimed by many—a total resistance below that calculated from results of trials of less carefully-designed vessels. This is no doubt true to a certain extent, but comparison between these American ships and those of other nationality, but of approximately the same lines and speed, shows still the superior efficiency of these vessels. The main cause of this increased efficiency lies in the use of three engines and propellers for the motive power. Not only has the propulsive efficiency been benefitted, but there are so many engineering and tactical advantages arising from the use of triple screws that it may be readily seen why so many ships are now designed for this system of propulsion.

The advantages due to the use of three propelling engines, instead of two, have been pointed out before, but it may be of interest to recall some of the reasons leading to the adoption of this system for the *Columbia* and *Minneapolis*. It was not possible, at the time of the design of these vessels, to obtain, in the United States, sufficiently large forgings for such great power as it was desired to install if the twin-screw system were adhered to. Other chief factors were the greater safety of the machinery and of the ship due to the use of three screws, as well as the then conjectured, but now proven, increased economy due to the use of triple screws.

To-day we have a somewhat different case presented in the design of high-powered cruisers or battleships. The conditions have changed. We are confronted no longer by the probable inability of the steel manufacturers to furnish forgings and castings of any size we may desire, for any power yet designed to be installed in a man-of-war. On the contrary, we have examples of engines of about the power we desire to use for our fastest vessels already constructed in the United States, and giving complete satisfaction, not only to the designers, but also to the builders and to the owners. The science of metallurgy

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has made such progress in the last decade that we are now able to specify, regularly, steel of 95,000 pounds tensile strength, 21 per cent. elongation in 2 inches, and to stand cold bending to an inner diameter of 1 inch without showing cracks or flaws. Improved methods of forging, our more thorough knowledge of fluxes, the exclusive use of nickel-steel for high-grade engine construction, the judicious employment of annealing and tempering—all these, combined, enable us to secure stonger materials, and now we obtain a vast increase of power without a much greater weight than that required ten years ago for the lower powers then prevailing. The reduction in weights is most apparent in the moving parts. This is an important point, as it has meant that the growth in power has not been accompanied by an increase in vibration, a matter that is likely to limit speeds of rotation in the future.

We are no longer forced to divide the power among three shafts because of the impossibility of obtaining one sufficiently large to transmit half the power. We can now secure in the home market all of the materials needed for the machinery of the highest power yet planned.

There are many other considerations, however, both tactical and engineering, which make it still advisable, at least for the highest powers, to use the triple-screw method of propulsion for our men-of-war.

The most evident advantage from the use of three screws is the consequent subdivision of the power. This is of particular moment on war vessels, where the possibility of disaster in battle is to be considered, as well as that of accident in time of peace. Not only does the increased number of engines decrease the probable amount of power that may be disabled at any time, but also the chance of fatal injury to the ship, through its motive machinery, is lessened greatly. The danger from a shell is decreased. It would require three shots penetrating the steel deck to completely disable a triple-screw ship, as against but two in the case of a vessel fitted with twin engines. This, however, is assuming a possibility which may not be a fact, that a shell will not have any disastrous effect outside of the compartment in

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which it explodes. It is probable that the vertical bulkhead between the engine rooms cannot be so entirely depended upon as to restrict the effects of an explosion. It is quite possible that a single very lucky shot might disable completely a twin-screw war vessel. If so, then it would surely take at least two such shots to inflict corresponding injury on any ship with triple screws. In case of the wrecking of any single engine the amount of power lost with twin screws would be one-half, as against the much less reduction of one-third in triple-screw ships.

It may be urged, and with justice, that the engines of our men-of-war are already well guarded from shell fire. If it can be shown, however, that the protection can be increased without consequent loss in other directions, it will surely be well worth while to adopt the system affording greater security. In the old days of sailing ships many a battle was won, sometimes against superior force, by the disablement of the sail power of one of the combatants. After the motive force of any fighting ship was gone, she was at the mercy of her foe. In our time, when battleships have a fair all-round fire, the likelihood of this is somewhat reduced; but it is still apparent that any ship which is inert on the sea is far the inferior of her dirigeable enemy. Any system which increases the chance of securing and keeping the "weather-gage" in battle, must be good.

Should one of the propelling engines be disabled, there is not nearly as much interference with what is called the handiness, the steering qualities of the ship, if there are three screws, as if there be but two. With twin screws and one only is use, it is necessary, in order to keep the vessel on her course, to use a helm angle of from 6½ to 10 degrees. This is the amount when the screw of the idle engine is left to revolve freely. We have attempted to get over this difficulty by using diverging shafts, and thus reducing the turning effect of the engines; but this is objected to by the deck officers who wish for vessels which can readily "turn on their heels." Of course, the less the fraction of the power that is disabled, the less the ill effect on handiness.

For war vessels it is desirable to make the water-tight compartments as small as possible. The reduction in the smaller

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sizes of engines in three-screwed ships leads to this end; and, as will be pointed out later, this is effected with no increase in the total engine-room space.

One of the greatest advantages from the use of triple screws is that smaller propellers are required for the same total power. This particular in itself presents sufficient advantages to justify the use of three engines on warships—advantages which are so practical, engineering and tactical, that it is surprising that this point has not been more thoroughly developed.

A very large part of the loss of power at the propeller is due to the frictional resistance of the water to the passage of the propeller blade. This resistance increases with any increase of the peripheral speed of the blades, and low speed will be advantageous in this regard. It is assumed, of course, that due account is taken of the ratio between the pitch and diameter of the screw. If this ratio be not unreasonably increased, however—and with the large hubs used in current designs, this ratio may be profitably rather high—it will be a great gain from an economical standpoint to reduce the peripheral speed. With very high speeds and powers this speed is now very near the critical point beyond which the friction is excessive, and the effects of cavitation begin to be felt. The decrease of pressure upon the forward sides of the screw blades, at high velocity, is not a negligible quantity. The matter of proper propeller design is too complicated to be more than glanced at here, but it must be evident that to reduce the peripheral speed would be advantageous in the cases of the screws of large diameter necessary in the application of very high powers.

Now, the use of three screws allows a reduction in diameter of screw of over 20 per cent., and while, as will be pointed out, this is accompanied by an increase in the number of revolutions, the speed of periphery may readily be reduced below what is required in twin-screw practice.

At the stern of the ship, amidships, in the following wake always present to some extent with the most carefully-designed hulls, the effects of a large screw are not so signally bad. I think that "cavitation," or the tendency thereto, is reduced

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greatly in this following wake, and, on that account, I believe that a considerably greater efficiency is obtained from the screw at the stern post than from those on the quarters. Whatever the cause, this increase in efficiency is so well shown by the results of trials that it can no longer be questioned.

I mean, of course, the trials of large ships, not tank experiments. The latter serve very well for determining the actual resistance of a hull; but not for fixing the economy of propulsion, or the ratio between the towing and indicated powers. It is in the increase of efficiency, and not in any decrease in resistance, that the economical advantage of triple screws must be found.

No test of a propeller can be held to have so much value as a test upon ships. Model experiments of propellers are not satisfactory. It requires experiments, with the full-sized screw, working at the designed pitch and at its designed speed, under its full load of work, to give us conclusive results. Trials under these conditions show, as I have said at first, a considerable advantage due to the use of triple screws.

Investigation along this line has not yet proceeded far enough to enable me to give more than tentative figures as to the propulsive efficiency due to the different methods of arranging the screws. It is, however, certain that there are gains from both the use of small screws, and of a screw working in the following wake, and that these gains would naturally grow with an increase in speed. Speaking only of full power trials, it will probably be found that, up to some low speed not yet determined, it will be best, from the economical standpoint only, to use a single screw; beyond this point it will be found that the use of twin screws would tend to a reduction in the power required for a given hull and maximum speed, and that, at any time where twin screws are good triple screws are better. I estimate the average economy over single-screw ships from the use of twin screws, as about 8 per cent. for vessels of maximum speeds from 12 to 20 knots, and I consider that triple screws are more economical than twin screws by from 5 per cent. for 15-knot ships to 12 per cent. for those of 24 knots speed. These figures

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are approximate; but they are from trial data of many ships fitted with the different methods of screw propulsion.

I have discussed this point at considerable length, principally to develop the following conclusions:

(1) The use of triple screws leads to a considerable economy at the highest speeds.

(2) Decrease in size of screws is peculiarly economical as regards the wing screws, and

(3) To evenly distribute the ill effects of high peripheral speed, and to take advantage of the following wake, the center screw should be made larger than the wing or side screws.

But there are many other advantages due to the smaller screws, particularly the smaller wing screws, and especially for men-of-war.

In ramming an enemy, if all goes well, there would be little difference between the twin and triple systems, but a glancing blow from either forward or aft would certainly take off the enemy's side screw if, as in twin practice, it projected beyond the counter; and, later on, as the ships rubbed past each other, one's own side screw would be broken, under the same condition of projection. But, with a small screw, such as can be had in the triple system, neither propeller would be damaged, and the stern screw would be safe in any event. This point is of value, too, in ordinary cruising, where a floating log or a pile in a river would disable a propeller of a twin screw ship, while the obstruction would have been pushed clear of the smaller propeller of a triple screw by the ship's hull. Going alongside dock also—that bugaboo to commanders of high-powered, fine-lined, speedy, twin-screw vessels—would be made much easier.

The shorter shafting required for getting the smaller propellers clear of the ship would allow these screws to be placed further forward, where they would be better protected by the hull. This shorter shafting would also decrease the strains on the propeller shafting in bad weather, and would often obviate the necessity of an extra supporting strut, giving, as well, a decreased danger of fracture and the possibility of decreasing the weight.

The fact that with smaller screws the tips of blades are lower

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in the water than with the twin-screw system, gives advantages. The design of the upper and fuller stream lines could be considerably freer. If it is considered advisable (and I have no doubt the hull designers will show that this gain is not of great moment where a central screw is fitted), this advantage could be passed over in favor of giving the wing shafting a slight inclination upward, so as to obtain a horizontal thrust when the stern of the vessel settles in the water at full speed. Ordinarily, however, the squatting of the ship would be insignificant. The fact must not be overlooked that the lower the propellers are placed the freer the access of water, and the more perfect the action of the screw.

With tips of blades well buried, the danger of racing is decreased, each extra foot of immersion reducing it. Anyone who has stood by the throttle, checking the engine with the heave of the ship, appreciates fully this advantage. The central screw, of course, would never race except in a sea where the ship was pitching heavily; while the side screws, being well forward and deep in the water, would probably never give trouble in the worst of seas.

When the use of three screws was first proposed, the idea prevailed in the minds of most engineers that the "race" of the water from the side screws would materially affect the action of the central screw. The error of this supposition was fully shown by the trials of the *Columbia* and *Minneapolis*. In the *Columbia* the pitch of all screws was made the same. The trials of this ship having shown the revolutions of the central screw to be less than those of the wing screws, the pitch of the central screw on the *Minneapolis* was made six inches less than that of the side screws. On the trials of the latter vessel the speed of rotation of the central screw was almost precisely a mean between the speeds of the two side screws, which differed slightly in pitch. This result was obtained without any "jockeying" of the throttle or change in the cut-off.

Attention has been called to the feasibility in the triple system of securing a greater number of revolutions, owing to the reduction in diameter of the propeller giving decreased friction of the

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blades. This matter of increased speed of rotation affects directly the efficiency of the machinery, especially in warships, where the stroke of the engine is limited by the height below the protective deck. The piston speed must be high to get the required power from modern machinery without too cumbrous low-pressure cylinders. Any increase in piston speed, or in the number of revolutions, decreases the condensation in the cylinders, as the item of time is one of considerable importance as far as this condensation is concerned. And, further, as a consequence of greater piston speed, we obtain lighter engines and shafting. For small powers, it is generally possible to obtain great piston speed in our low naval engines, by a great number of revolutions; but there has been pointed out the difficulty of obtaining efficient propellers at high rotative speeds, for transmitting great powers. We know, of course, that it is possible to get an efficient propeller for the very highest powers yet used; but these propellers must be of great diameter in large ships, and in the United States we look into the matter of draught very closely. Our vessels are built for entering comparatively shallow harbors, and it is not easy to secure a screw that will be efficient, and that will fit on a 22-knot, 12,000-ton ship of no more than 24 feet draught. There must be a certain minimum immersion of the screw blades, and this must be greater for twin-screw than for single-screw vessels, because of the rolling of the ship. It is necessary, also, to have a considerable difference in level between the keel and the lowest part of the screws in a twin-screw vessel. It will surely be difficult, and, I believe, impossible, without the use of high glacis plates, to obtain satisfactory machinery for twin-screw ships under the conditions named, 22 knots, 12,000 tons and 24 feet draught.

In the design of marine machinery, it is important that the ratio between the stroke and the diameter of cylinders be kept sufficiently high. This ratio is necessarily low in all naval vessels, as compared with the merchant service, on account of the necessity of keeping the machinery below the protective deck. Of course, the larger the power and size of the low-pressure cylinder, the longer the stroke should be, and therefore the

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greater the height of engine room required for a properly-designed engine. The greater the draught, the greater the possible height of engine room, and, for the same number of revolutions, the greater the piston speed. It is unquestionable that, where more than, say, 10,000 horsepower is to be transmitted through a single shaft, under present conditions of speed and displacement, the number of revolutions will be limited by the propeller. We, in the United States Navy, having ships of very light draught, as compared with other fleets, are most hampered in this regard.

It has been shown that the use of triple screws would tend to a decrease in the volume of the cylinders required for giving the powers. This is quite apart from the fact that the power is divided into three parts instead of two, and is due to the greater piston speed possible with the smaller screws. It will be seen, then, that considerably more latitude is allowable in the design of machinery for ships with triple screws than would be possible if twin screws were used. If three engines are installed, it is certain that a less height is required under the protective deck than would be necessary for a twin-screw ship.

It is to be noted, then, that the economy of a triple-screw ship is developed not only in more efficient propulsion, but also in the more efficient use of the steam in the engines due to the decreased condensation following the increased number of revolutions and the greater piston speed. The economy of propulsion is thus increased as a result of both increased propulsion efficiency, and of increased efficiency of the engines. A decreased total weight of the machinery is also a natural result of the use of triple screws.

It is, of course, a fact that the use of three engines multiplies the number of engine parts. The resulting disadvantage is, however, much more apparent than real. The *Columbia* and *Minneapolis* are examples of the practicability of installing large power in three three-cylinder engines, and this was accomplished with a stroke of but 42 inches. There is no doubt that it would have been necessary to use four-cylinder engines, at least, if twin screws had been used. The absolutely necessary increase

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in the number of cylinders is thus shown to be but one-eighth. Of course, it is understood that the use of three-cylinder engines is now generally approved. It is merely pointed out as feasible, and as intended to show that the arguments against triple screws, based on the multiplicity of engine parts, could readily be made of practically no weight, if other conditions did not render advisable an increase in the number of cylinders.

Water-tube boilers have now come to stay, at least as far as the United States Navy is concerned. These bring with them steam of high pressure, and cause the use of quadruple-expansion engines for economy's sake. At 200 pounds pressure the quadruple-expansion engine gives sufficient gain to justify its employment. Owing to the low powers of peace cruising with men-of-war, it is questionable whether it is desirable, with these ships, to design engines for the greatest economy at the highest powers. Unquestionably an arrangement of cylinders which gives the greatest economy at the highest powers produces a markedly uneconomical engine for the lower powers ordinarily used in peace.

The wide variations in present designs show how different designers view this problem. It is extremely complicated, and I am free to confess that much more data than are now available are needed for a full solution. We must know the cost of running the auxiliary machinery, and not only the average power of the main engines, but their range of power must also be carefully considered. It has been thought advisable, however, in the design we are proposing for our latest fast ships, to use quadruple-expansion engines throughout, using thirteen cylinders, in all, in the three main engines. This is a considerable change from the practice of twenty-five years ago, when two cylinders were most frequent. But the fact that this large number of cylinders has been adopted shows that our experience, at least, is that the argument of the multiplicity of parts of the engines has comparatively little weight. The decrease in the size of parts, with the consequent increase in accessibility, in accuracy of adjustment, and in case of repairs, is a natural sequence of the growth in the number of parts, and seems sufficient to

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overcome the disadvantages. It will be pointed out, further, that the increase in the number of working parts due to the use of triple screws is only apparent, as, ordinarily, there would be not more than eight cylinders employed on our triple-screw ships against ten cylinders that would necessarily be used in the proposed five-cylinder quadruple-expansion engines for our twin-screw ships.

A much more serious objection to the use of triple screws than the multiplicity of engine parts is found in the greater intricacy of the piping plans, and in the increased number of valves required. This objection is serious. Our twin-screw warships are complicated enough at best. This disadvantage has been reduced somewhat, however, by several simple methods. The use of electrically-operated auxiliaries has done much in this respect, especially as regards piping outside of the machinery space. Our piping plans are very carefully studied, and are so designed and arranged as to reduce the number of valves to a minimum, and to render plain to the engineer the leads of all pipes. All valves are marked mainly to show the connections. Many of them indicate, as well, the amount of opening of the valve. As a result of this care in the laying out and installation of piping and valves, mistakes in the operation of the valves are made almost impossible, and undue intricacy of the piping plans is avoided. This absence of complexity is especially marked when comparison is made with some of our earlier twin-screw ships.

The growth in number of auxiliary engines, owing to the employment of three main engines, is another disadvantage of the triple-screw system that is much more apparent than real. Ordinarily there is no increase in the number of auxiliaries in use, only an increase in the number available for use; and, as a rule, these uneconomical auxiliaries are worked much more nearly at their rated capacity, and are thus considerably less wasteful of steam. Our experience has been that the auxiliary machinery gives most of the trouble on board ship, and our vessels have been more frequently disabled on the account of the failure of these small engines than from any other cause due

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to the machinery. A larger reserve power in this, the weak part of the machinery, is too great an advantage not to be well worth its cost.

The increase in engine-room force required with the three engines is not excessive, being twelve men at the most. This cannot be considered a disadvantage for warships. The added staff consists entirely of skilled mechanics, and these men are especially useful in making repairs while under way. Our recent war experience tends to show the imperative necessity of some such mobile reserve for the maintenance of a vessel, constantly under way, in a condition, at all times, of thorough efficiency. With this increase, there is always some one at hand to take the place of any man overcome by heat or sickness, and crippling of the crew, as well as of the machinery, is guarded against. I repeat that the increase in the engine-room force necessitated by the adoption of three propelling engines cannot be counted a disadvantage in men-of-war, under war conditions.

The formation of the stern post and rudder is made somewhat complicated by the use of the central propeller, but not more so than in any single-screw merchantmen, and I apprehend that this disadvantage will not be given great weight to by any designer.

To obtain a proper conception of the advantages of triple-screw propulsion it is necessary to consider also the latitude afforded by this system in the methods of running the ship under cruising conditions, since either one, two or three screws may be used. There have been many trials of triple-screw ships under each of these methods of propulsion, and it may be interesting to give a few of the results, which have not hitherto been published, so far as I am aware. Taking a vessel of, say, 12,000 tons, 23,000 H.P. and 22 knots speed, when all engines are used at full power, it is found that—

(1) The power to drag one screw, uncoupled from the engine and left to revolve freely, is 150 H.P. at 10 knots; 600 H.P. at 15 knots.

(2) If coupled to the engine, at 10 knots speed the power absorbed in dragging is slightly in excess of 300 H.P.

(3) If two screws are dragged, the loss from drag is practically

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double what it would be with one idle screw for the same speed of the ship.

(4) The loss in power due to condensation in an engine (not the result of expansion of steam in the cylinders, but attributable directly to the heating of the cylinder walls) is almost exactly one pound of steam for each horsepower of the maximum power for each engine. This figure is approximately correct for all speeds, increasing slightly for the lowest speeds. It applies to jacketed engines.

(5) With three equal screws, the center propeller has not sufficient area to give economical results when used alone at speeds above eight knots. With three equal screws, the use of the two wing propellers alone can be depended upon to give a considerable gain in economy for all speeds from 8 to 17 knots inclusive. These results have been gathered from fully authenticated trials, not only of our own ships, but also of triple-screw ships in other navies.

All screws are practically equal in disc area in the trials from which these results are obtained.

With these points known, the problem of the design of triple-screw ships is greatly simplified. The disadvantage of the drag of a screw is measured, and the advantage of the fitting hitherto adopted, which provided for the disconnecting of any idle screw from its engine, is clearly developed. The necessity of giving sufficient disc area of propeller is, as was to be expected, prominently shown by the failure to secure economy with one engine in use, except at the very lowest speeds.

The value of economical engines is so universally recognized to-day that it seems almost unnecessary to mention it; but this value is, in a warship, far greater than the mere saving in the coal bill, though that is an important item. The matter of economy in the use of coal may make all the difference between victory and defeat. Coal endurance limits the radius of action of the ship, and determines definitely the scope of her operations. Of course we can—as we did recently in two cases—assist a monitor across the Pacific Ocean in case of need, but that tardy reinforcement might have been too late. Economy at the engines

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increases the speed of these reinforcing ships where that economy can be gained without a reduction of bunker space; it increases the potential value of each pound of coal, and 10 per cent. may often make the difference between success and failure. If this economy were measured alone, and not from the military point of view, it might be proper to consider the question whether three engines have a greater first cost than two of the same total power, but economy means more than that. It means victory, and it is for this that men-of-war are built.

If three screws are to be fitted to a warship, and the design is to conform to the conditions of economical propulsion obtaining on these vessels, as shown by our present knowledge of the effects of three screws upon propulsive and engine efficiency, there appear to be but two practicable arrangements. The central engine should be considerably more powerful than either of the wing engines, or it should be considerably less powerful. This follows from the fact that a propeller design which will give in one screw sufficient area for the ordinary cruising speeds up to 12 knots, is nearly impossible if the same screw is designed to be worked as one-third of the propelling system for the highest speed of the ship. The proportions of the screw must be changed to suit the latter conditions. It is evidently not wise, also, to use as much as two-thirds of the full engine power for cruising at one-tenth power. The use of three equal engines is, therefore, out of the question, as far as comparative economy goes. If a small center engine be used, it would be practically an auxiliary. A very large screw necessarily being fitted to secure a fair propeller efficiency at low speeds, when the small engine alone would be used, it would be of practically no value at the highest speeds. I consider, therefore, that it would be far better practice to use a large center and two small wing engines, in which design under no conditions would there be a useless engine. Of course, either of these plans, involving the use of two different sizes of engines on the same ship, is disadvantageous; but this disadvantage is not so great as a casual view of the conditions would seem to indicate. Engines do not break down in service. Careful designs for the maximum power insure good working of the machinery. Accidents to the en-

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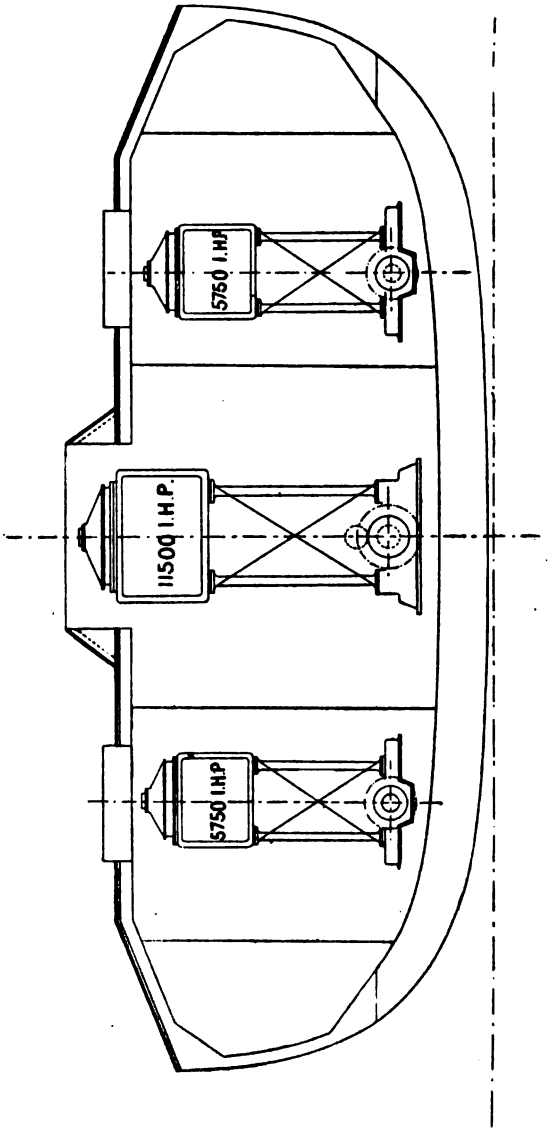

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gines are extremely rare, and are due, almost invariably, to some defect in a seemingly unimportant detail. The engine itself, so far as its large parts are concerned, does not break down, and a supply of the lighter spare parts provides for all emergencies, such as are ordinarily met. On the other hand, it is well to note the many advantages due to the use of different engines. There is, in particular, much to be said in favor of the plan of installing small wing engines in a triple-screw ship. It is a fact that commanders of our ships hesitate, as naturally they should, to enter or leave a port with only one screw in use. They desire to retain the practical advantages of handiness accompanying the use of twin screws. It is, further, a fact that ships which ordinarily cruise at speeds of from 14 to 16 knots we have found to make better speeds in time of war than ships of the same class, but of lower cruising speed. These conditions, combined with the proved efficiency of the use of the wing engines at speeds up to 17 or 18 knots, have been with us the determining factors in causing the adoption of designs involving the use of the smaller wing engines. It has been found advisable to fit economical machinery for cruising at speeds as high as 16 knots. While engines which will be most economical at this speed will not be the most desirable in this respect for a speed of 10 knots, they will retain considerable advantage over any other system in the reserve which will be ready for instant use.

The problem of the design of the propellers to give a proper efficiency for low speeds, and to be good also at the highest speed, offers in this system no difficulties. The reduction in the size of the wing engines, below what would be necessary if three equal engines were used, effects a saving of about 200 H.P., or its equivalent in steam due to the decreased condensation on account of the smaller engines. This figure applies exactly to our recently-designed 22-knot armored cruisers. The ship is economical at all the ordinary cruising speeds from 10 to 17 knots. The tactical advantages of working with twin screws are retained at all speeds, high or low. It has been pointed out that the decrease in size of screw is especially advantageous for the wing screws, and that it is advantageous, on account of the superior propulsive efficiency of the screw working in the follow-

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ing wake, to have a large power on the center engine. These conditions are especially well fulfilled by the use of the smaller wing engines.

To reduce the engine-room space it is advisable to place engines abreast in the ship. It is also a great advantage to arrange the engines in this way, as it makes possible the placing of a part of the boiler power abaft the engine, which gives easy solution to all problems connected with the change in trim due to the use of light water-tube boilers, and also reduces vibration by placing the engines in the strongest part of the ship. In fact, the center and most powerful engine is exactly at the point of greatest resistance of the hull to vibration. By using smaller wing engines it is also easier to arrange the engines abreast than it would be to install twin-screw engines of the same total power. This follows from the lozenge shape of the space available for the engine rooms beneath the sloping protective deck and above the rising bottom of the ship. Again, but one screw is dragged with the two engines in use. This screw is a large one, it is true, but the drag is probably not so great as it would be with two smaller screws of the same total power.

It is also regarded as an advantage for this system that there is always one-half the full power available in case of accident.

The center engine is seldom used, and our experience goes to show that it is always in a condition of very good efficiency. The customary employment of the smaller wing engines insures ease of making the regular repairs. It is but fair that I should state that, with its very large screw, designed for transmitting about half the total power at full speed, the use of the center engine alone may prove slightly more economical than that of the wing screws for a speed of about 10 knots, this superior efficiency following from the working of the screw in the following wake. I do not expect, however, that the center engine will often be alone employed, as the maneuvering qualities and general handiness of the ship are so much improved by the use of two screws at all times. It should, however, be pointed out that the handiness will be retained at full power, and will not be affected badly by the reduction in the size of the wing engines.

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In a word, the arrangement of triple-screw engines, with approximately one-half the total power placed upon the center engine, and approximately one-quarter on each of the wing engines, seems to fit a warship and its conditions remarkably well.

Ramming and torpedoing would lose much of their danger with the small engines outboard. There is a certain prejudice among naval officers against any system that shows so plainly as do triple screws the enormous amount of power installed in the ship and so seldom employed. These officers would possibly prefer to imagine all the power in use, even when knowing, as they all certainly do know, that frequently not 10 per cent. of the total power is actually being developed. The loss from drag of an idle screw is plainly seen, but they forget the loss in the engine cylinders from condensation, which is often much greater. Not to employ ordinarily the reserve-power plant increases the value of this reserve as well as the economy. It may appear unwise to install a plant that is so seldom used, yet when the power is wanted it is wanted badly, and at such times every pound of coal in the bunkers may be worth a ton at ordinary times.

The use of two screws with two engines upon each shaft has not been considered as an alternative to the use of triple screws. This arrangement, with its four engines, has nearly all of the disadvantages attendant upon the use of three screws, with very few of their advantages. Further, it presents the grave tactical disadvantage which was developed so fully in the cases of the *Brooklyn* and *New York* at Santiago. These vessels were fitted with four engines working twin screws, the forward engines being ordinarily uncoupled. This system was designed to insure economical running at low speeds; but it was impossible to couple up the forward engines without stopping the ship. During the battle of Santiago, stopping the ship for the fifteen minutes necessary to couple up the engines would have been fatal. On the contrary, in the case of the *Minneapolis* the center screw was coupled up while the two wing screws were driving the vessel at a speed of 17 knots. This was done when the

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ships of Admiral Schley were sighted off Santiago, and before the identity of his fleet was established. It is a great advantage that full power can always be applied on a triple-screw ship without stopping. Such conditions would surely have been very valuable to the *New York* at Santiago.

It may naturally be inquired why the superior efficiency due to the use of triple screws has not led to their general adoption in the merchant marine. Triple screws undoubtedly would have been used in that service if the conditions obtaining were the same as those existing in the Navy. Merchant vessels, however, instead of running at a variable speed, are always worked at their full power, and there would be, consequently, no advantage to their owners in fitting machinery capable of working economically at low speeds. The stroke of engines in these vessels is also not limited by a protective deck, and it is always possible with them to obtain the great piston speed necessary for economy by increasing the height of the engine. We see, therefore, that two of the main reasons for the use of triple screws in men-of-war do not obtain in the merchant service. Added to this must be the fact, that the cost of building and installing three engines, when not all of the same size, is considerably greater than that of two engines of the same total power; and also, that the cost of maintenance due to the larger force required would be considerably increased. From these considerations it would appear that triple screws may not be desirable for the merchant service, under present conditions of size and speed. I think, however, that any transatlantic line which would definitely adopt the triple system, would be patronized by a considerable number of persons, because of the greater security afforded by its use.

The statements I have made as to the desirability of using three screws on war vessels, and the fact that they are being used to so great an extent in the Continental Navies, will naturally lead the thoughtful student to wonder why they have not been adopted, to some extent at least, in British vessels. This feeling will be the stronger from the fact that British engineers are justly considered to be thoroughly progressive, and abreast

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of the times with respect to every feature that would tend to an increase in the efficiency of vessels.

It has occurred to me that, whatever other reasons may have caused this non-use, until now, of triple screws on British vessels, one feature of the case at least may serve as a partial explanation. I am led to this belief all the more from the fact that it agrees with the experience of all designers with respect to some forms of marine machinery which, while apparently very peculiar, are the best adapted to the particular cases where they have to be used, viz: the exceedingly light-draught steamers required for certain river service.

Yacht designers are very familiar with the fact that vessels designed for general cruising on the English coast are very different from those for general use on the coast of the United States, due to the fact that in England there is everywhere an ample depth of water, while in the United States the reverse is the case.

In just the same way, we in the United States are restricted in the draught of our war vessels to about 24 feet, while the large British ships can, and do, in some cases, draw about 27 feet. As a consequence of this radical difference in the circumstances under which large powers have to be applied, the problem of the number of propellers is presented to the designers on the two sides under a different aspect, and I am inclined to believe that this has had a great deal to do with the fact that British designers have not paid much attention to three screws thus far. Had they been compelled to face the problem of putting large powers in light-draught hulls, I think they would have been driven to a consideration of the advantages of three screws, and probably would have taken hold of the matter with their characteristic energy.

Let me add, in conclusion, that I have given this subject of triple screws very careful study, and I believe that for war vessels their use is thoroughly logical.

Further than that, I believe that, although contrary to the generally accepted idea of duplication of parts as far as possible, the plan which I have suggested for dividing the power between

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one large central engine, to develop about half the power, and two smaller wing engines, each of about one-quarter power, will give the best results, and is likely to be the system that will finally obtain general adoption.

THE CASE OF TRIPLE SCREWS.

Their Advantages.	*Their Disadvantages.*
Smaller engine parts.	Greater number of parts.
Greater ease of overhauling.	Greater number of valves and pipes.
Greater accuracy of adjustment.	Greater number of auxiliaries.
Lack of vibration.	Increased engine-room force.
Subdivision of power.	
Increased (probable) available power.	Loss of power due to drag of idle screw.
Increased ease of protection.	With center engine alone used, the loss of tactical advantages due to twin screws.
Increased handiness when partly disabled.	
Smaller water-tight compartments.	
Smaller propellers.	
More efficient propellers.	
Less peripheral speed of propellers.	
Less screw friction.	
Increased revolutions of engines.	
Decreased loss from cavitation—the word being used in its broadest sense.	
Increased efficiency of the screw working in following wake.	
Decreased danger to propellers in ramming.	
Decreased danger to ship that is rammed or torpedoed.	
Shorter propeller shafting.	
Decreased racing of screws.	
Freer design of stream lines.	
Freer access of water to screws.	
Increased piston speed and economy.	
Decreased total size of cylinders.	
Decreased weight of machinery.	
Decreased condensation in engines at all —especially at low—powers.	
Adaptability to light draught.	
High ratio between stroke and diameter of cylinders.	
Less glacis plating required.	
Ease of propeller design.	
Latitude of engine design.	
Great gain in economy at low powers.	

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THE CASE OF THE PROPOSED SYSTEM OF TRIPLE SCREWS WITH SMALL WING ENGINES.

Advantages.	*Disadvantages.*
IT FITS THE SHIP.	Two sizes of engines in same ship.
Ease of installation and design.	Increased cost of building.
Great gain in economy at all speeds.	Increased number of spare parts necessarily carried.
The tactical advantages of twin screws economically retained.	
Engine-room space is reduced.	
The powerful center engine has a most economical screw working in following wake.	
The vibration is minimized.	
The loss from drag of screw is minimized, one screw only being dragged.	
Small size of working parts.	
Two independent plants, each capable of economical propulsion up to fifteen knots speed.	
Small size of working parts, with maximum ease of repairs.	

The disadvantages are few, and, from a broad standpoint of military excellence, they are unimportant. The advantages are many, including better design and installation, greater ease of maintenance, and greater efficiency at all speeds. I consider this the logical arrangement of motive machinery on high-powered warships.

Discussion.

The following letter from **Mr. Magnus Sandison** (Member) was read by the Secretary at the commencement of the discussion:

Newcastle-on-Tyne, *March 22, 1899.*

The Secretary, Institution of Naval Architects.

Dear Sir: I am sorry I am unable to be present to-morrow at the discussion on Admiral Melville's able paper on the propulsion of vessels fitted with triple screws.

Admiral Melville gives some very interesting figures regarding the power required to drag uncoupled screws in the case of such vessels, and lays very great stress upon the necessity for economy in coal consumption when cruising.

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He says: "If three screws are to be fitted to a warship, and the design is to conform to the conditions of economical propulsion obtaining on these vessels, as shown by our present knowledge of the effects of three screws upon propulsion and engine efficiency, there appear to be but two practicable arrangements. The central engine should be considerably more powerful than either of the wing engines, or it should be considerably less powerful."

Having in view the vast difference in the power required to propel a cruiser at eight or ten knots as compared with the power required to propel the same vessel at a speed of twenty-two or twenty-five knots, and the very poor performance of the twin engines at the lower speeds, I prepared a design of machinery about seven years ago which embodied the second of Admiral Melville's proposals.

My idea was that the vessel should be propelled at the lower or cruising speed by a small engine of only sufficient size to develop the requisite power, and so proportioned as to develop that power with an economy equal to that attained in the best examples of the Mercantile Marine, the shafts of the main or "wing" engines being uncoupled forward of the thrust blocks leaving the propellers free to revolve.

This "cruising engine" was to be of substantial design and adapted for continuous steaming at full power over long periods. It was to be accommodated aft of the main engines in a separate watertight compartment, or even placed at the aft end of the vessel in the same compartment as the steam-steering engines.

Steam was to be taken from an auxiliary steam-pipe system in one, or other, of the engine rooms, and the engine would either have its own condenser or one, or other, of the auxiliary condensers could be utilized. These condensers are, of course, only worked to their full capacity when the main engines are developing a large percentage of their maximum power, and the forced-draft fans and other auxiliaries are running at a proportionate speed.

The propeller of this engine, to reduce its resistance when the vessel was being propelled by the main engines, was intended

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to be of the feathering type; or, of course, the engine could be run in conjunction with the main engines.

There is no doubt but that many advantages would accrue from the adoption of some such arrangement.

Yours truly,

MAGNUS SANDISON.

Mr. A. E. Seaton (Member of Council): My Lord and Gentlemen, no doubt this paper is a very interesting one, very ably prepared and written. We are very much indebted to Admiral Melville for giving it to us, and thereby adding another very good reason for regarding the Institution as of international interest. I think the Admiral, however, has rather stretched his case further than was necessary, and has adopted what I may almost call special pleading in many cases, which will scarcely bear very close investigation. No doubt he has made out the very best case possible for three screws, and, in doing so, has magnified to the very utmost the advantages of the system, and minimized to the very utmost the disadvantages. He says he is a little at a loss to understand why the triple screw has not been adopted in the British Navy, and he almost hints that it is in part due to our conservatism. Perhaps that is so; but, it may be interesting to him to know, and to you, gentlemen, also to know, that three screws were tried in the British Navy some forty odd years ago. It is true the trial was an accidental one, but nevertheless it was an interesting one, inasmuch as it was resorted to for the very reason that the Admiral urges as one of the best for the adoption of the triple screw. Some of our older members may know better than myself—I only know the circumstances by hearsay, but I believe it arose in this way. During the Russian war one of the floating batteries* built, developed such a very poor speed that some-

* H.M.S. *Meteor*, 1,469 tons, 172 feet 6 inches by 43 feet 11 inches; draught of water, 6 feet 5 inches forward, 8 feet aft. When tried with a single screw, 6 feet diameter and 12 feet 6 inches pitch, the speed was 5.77 knots; the revolutions being 139, the I.H.P. 530, slip per cent., 66.3. With two screws added, each 6 feet diameter and 7 feet 6 inches pitch, the speed was 5.23; the revolutions 113, the I.H.P. 498, slip per cent. of center screw, 62.46, wing, 37.4.

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thing had to be done. She had, of course, a single screw. The authorities at that time came to the conclusion that it was due to the smallness of the screw, and as her draught of water did not permit of a larger screw some other means of increasing the speed had to be adopted. It was then suggested to fit two wing screws, driven by gearing from the main engine; in this way we had, for the first time in the Navy, a three-screw ship. I understand the result was not satisfactory, because I have no doubt that any improvement that might have been got by the three screws was prevented by the excessive friction of the wing gearing. Admiral Melville speaks of the economy due to the three screws, and says, "I consider that triple screws are more economical than twin screws by from 5 per cent. for 15 knot ships to 12 per cent. for those of 24 knots." He does not say how he arrives at that, and they seem to be rather big figures. The economy, of course I take it to be in horse-power or coal consumption, but when we come to the economy of cost, he deals very lightly with it, and does not mention any percentage. In spite of what he says as to the usefulness of the increased engine-room staff, I scarcely think that is a good reason for three screws, inasmuch as in a twin-screw ship, if the advantages of the staff are as he suggests, and no doubt some of them are perfectly true, you could get them. The advantages he speaks of certainly would not exist in war time, when a ship is liable at any time to be called upon to go at full speed, and if any of the crew were sick or ill there would be no surplus staff, and the chance of repairing would disappear altogether.

I do not agree with the Admiral that there is any advantage in triple screws for ramming purposes. I think myself, when it comes to ramming, whether the screw is a foot more or less below the water, or a foot more or less inboard, if the ram approached the counter of the ship the outer screw of the triple-screw ship would be equally liable to damage as an ordinary twin-screw ship. I do not agree with what the Admiral says as to racing in rolling. It is not our experience that engines do race in rolling; in fact, most ships roll *with* the waves, and not *to* them, and consequently the screws do not come out of the water in the way we imagine.

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Nearly all racing in twin-screw ships is due to pitching. We also think, with good reason, that the twin-screw ship does not race to anythng like the extent that the single-screw ship does; therefore, for the same reason that the single-screw ship races, the center screw of the triple-screw would race considerably.

The Admiral deals also somewhat lightly with a subject that came very greatly to the front some thirty or forty years ago, when sailing ships with auxiliary engines were fashionable. I think Dr. Scoresby points out more than once in his Diary what a nuisance the engines were in the *Royal Charter*. He went, as you know, on a voyage to Australia, to observe the effect of the magnetism on iron ships. This ship had a small engine capable of driving the ship at seven knots. The engine used to be started in calm weather, or when the winds were light, but if a breeze sprang up, and the ship began to gather way owing to her sails, and the speed went up to nine or ten knots, the engines raced so badly as to shake the ship dreadfully. Then the old question came up, which the Admiral has also dealt with, of coupling up and uncoupling, which was found to be no easy matter. For these reasons the engines in the *Royal Charter* were never used to the extent intended.

I do not quite follow the paper on pages 3 and 9 as to the numbers of the cylinders. In the paragraph at the bottom of page 3 the author says, "using thirteen cylinders, in all, in the three main engines." I can only suppose that he means that the wing engines are to be four-cylinder quadruples, and the center engines five-cylinder quadruples. Again, I am a bit puzzled as to the number of cylinders on the top of page 9. He says: "It will be pointed out, further, that the increase in the number of working parts, due to the use of triple screws, is only apparent, as, ordinarily, there would be not more than eight cylinders, employed on our triple-screw ships against ten cylinders that would necessarily be used in the proposed five-cylinder quadruple-expansion engines of the twin-screw ships." That is probably a misprint, and it may be capable of explanation.

In dealing with the capacity for repairs, due to increased engine-room staff, he has not laid great stress upon, or called

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special attention to the fact that there would be more engines requiring repair—three engines as against two, and he has not spoken very much about the auxiliary engines and fittings that would be increased by the three engines.

What he says about auxiliary machinery is interesting. It appears in the American Navy more trouble has been caused by that than by almost anything else, and it leads one to consider the subject as one of primary importance, and to ask oneself whether the time has not come when the distribution of power on a warship should not be arranged pretty much on the same plan as we find on shore to be the best, namely, by using electrical motors. We have in them a very simple instrument, which is not very apt to go wrong, which is much more economic than the ordinary auxiliary steam engine on board ship, and whose power is generated by two or three highly efficient engines as against the power generated by twenty or thirty highly inefficient engines. I think that most of the auxiliary work on board ship might be done in that way. I am aware that there are those who claim advantages for the distribution of power by hydraulic pressure; but, on the whole, I think for a warship it is safer to use electricity. If three engines are to be fitted in a ship—and it must not be supposed in the remarks I am making I am altogether throwing cold water on the three-engine type of ship, I trust I am only criticising it in an impartial and fair way—but, if three engines have to be fitted to the ship I think there is no question but that the center engine must have considerably more power than the wing engines. The Admiral has not mentioned it, but no doubt an advantage would accrue if the center propeller were made two-bladed; because, when not in use it could be very much shielded by the body of the ship, and the drag would be very much lessened.

I do not, think, my Lord, I have anything further to say, except that this is a most important paper on a highly important subject, and I have no doubt that the debate which will take place to-day will put the pros and cons so as to permit us to view the matter as none of us have hitherto seen it.

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Professor J. H. Biles (Member of Council): My Lord and Gentlemen, I am sure that you will all be pleased to have heard this paper from so eminent an engineering authority as Admiral Melville. It may not, perhaps, be very well known to some of the members of this Institution that before Admiral Melville was eminent as an engineer he was eminent as an Arctic explorer, and those who have read his charming book on "Through the Lena Delta" must be familiar with the fact that the energy he displayed in carrying that expedition through, or the remnants of it back to civilization, has been of value to him and to his country in carrying out the reconstruction of the United States Navy. In 1891, I had the honor of reading a paper on some recent American warship designs. At that time the ships which are referred to here by the Admiral were on paper, and just about commenced in construction. They were familiarly called in the American office the pirate—the design was called the pirate—the intention being that these ships were to be made so fast that no warship could catch them, and that they should prey upon the commerce of an enemy. They have been promoted since then from the rank of pirate to that of cruiser, and in the work that they did in the recent war they gave some very good and economical results.

Now, this paper of Admiral Melville is, as Mr. Seaton has said, open to some amount of criticism from the point of view that he tries to prove a little too much; that is on account of his enthusiastic nature; but it does not detract, I think, from the real advantages of triple-screw ships in certain cases. It seems to me, after reading his paper and knowing that that paper has been written after the whole question of the new designs for three-screw armored ships had been fully considered by the Navy Department at Washington, that the summary of it amounts practically to this: that as an alternative to a twin-screw ship, he takes a three-screw ship, into which he puts one of the two twin-screw engines divided into equal parts. Now, in some of the twin-screw ships there were four engines, such as the *New York*, the *Brooklyn*, and the *Blake* and *Blenheim*. If we depart from this point of view we see that he has taken one of those

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sets and put each of the separate engines to the side screws and turned the other two sets into one set and put it at the middle line. In comparing the efficiency of the three-screw with the two-screw, one advantage that is due to the change of size of engine, say only half, applies only to one-half of the machinery in this type that experience has shown to be desirable in the triple screw. So that, what Admiral Melville commenced by saying, that there was a great advantage due to reduced sizes of the engine, can only half apply to the case they have evolved by their experience. The other dominating consideration certainly seems to be the question of draught. If you have a limited amount of draught, it is easier to have propellers with three engines than it is with two. But, of course, in addition to the possibility of getting in three screws on given draught there is the advantage that if you do adopt three screws, which are smaller with engines of equal power, even in a ship where draught is not absolutely limited, you get a better performance at sea in bad weather.

There is, unfortunately, in this paper no distinct positive statement as to facts upon which the improved efficiencies are based. The facts have already been given in a paper which Admiral Melville read before the Society of Naval Architects and Marine Engineers in the United States, or the facts that he had at his disposal; but his determination in that paper, so far as I remember it, of the propulsive efficiency of the triple screw—and, of course, it is really the pith of the whole of his argument that the triple screw is more efficient as a propulsive instrument—the method he used for determining this propulsive efficiency was to assume a certain net resistance to the hull. Now, those who are familiar with model experiments and the results of them will not, I think, be quite prepared to accept an estimate of the resistance of a hull which has not been tried in a tank; or, if some form very closely approximating to it has not been tried, and, therefore, so far as the two vessels referred to by Admiral Melville are concerned, I doubt very much whether the assurance he gives is quite as satisfactory as it ought to be—that the propulsive efficiency is so much higher. If we judge

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of propulsive efficiency by the general method that is adopted by those who have not tank experiments available—that is the Admiralty constant of performance—then I do not think there is anything very remarkable about the performances of the *Columbia* and *Minneapolis*.

The statement that Admiral Melville makes, that a twin-screw ship is more efficient than a single-screw ship, and has a higher propulsive efficiency, seems to me to detract somewhat from the efficiency of the triple screw. Within my experience the best results of propulsive efficiency that I know of are certainly on single-screw ships, and I was rather under the impression that the advantage of the triple screw in propulsive efficiency lay in the fact that the center screw obtained the higher efficiency which is sometimes obtained in a single screw over a twin screw. Admiral Melville lays some stress on that when he says the center screw picks up the frictional wake of the ship and gets some power back on that account.

The statement on page 7, that "it is unquestionable that when more than, say, 10,000 H.P. is to be transmitted through a single shaft under present conditions of speed and displacement the number of revolutions will be limited by the propeller." That statement seems to me to want some qualification. Surely it is easy to reduce the diameter of a propeller and increase the number of revolutions, and the statement that the number of revolutions will be limited by the propeller, I think, wants some qualification.

Mr. Seaton has pointed out that, on page 9, what is claimed as an advantage for having a larger engine-room force is not a real advantage, because there is more work for the men to do. The statement with reference to Transatlantic ships, that three screws afford a greater security than two screws, I think really cannot have very much weight. The difference between one and two screws if you have a breakdown is the difference between having one engine and no engine, but the difference between two and three screws if you have a breakdown is the difference between having one engine and two engines, which

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is comparatively of small importance in such unusual circumstances as the complete breakdown of one engine.

Sir William White, K.C.B., LL.D., Sc.D., F.R.S. (Vice-President): Lord Hopetoun and Gentlemen, I should have preferred to have intervened in this discussion later, because I am quite sure that my voice is heard here too often, but this is a subject in which I take, and have taken for the last twenty years, the keenest interest, and on which, I think, we shall be all glad if we can obtain more definite information. It will be remembered by members of this Institution that, about twenty-one years ago, I read a paper here in which I strongly recommended the use of twin screws in deep-draught ships. At that time that was not a popular view, and in some of the engineering publications at that time I did not have a very appreciative reception; but events have justified the view that, as speeds increased on a limited draught, twin screws would come in. And they have gone further than that, as I always thought they would; twin screws have come in as desirable features in propulsion where there has been no question of limited draught, for example, in the great cargo carriers of comparatively moderate power. I simply recall that circumstance, not in any spirit of self-glorification, but to indicate that, so far as possible, I keep an open mind on all these subjects.

I trust I have no prejudice except the prejudice of trying to find out what, under a given set of circumstances, is the best. I have had some difficulty in dealing with this paper, for two reasons; one is, that it contains a great many contentions, not a few speculations, some arguments, and very few facts. Now, in this matter, facts are what we want. My paper of 1878 was nothing but a summary and an attempted analysis of facts. When I heard that Admiral Melville, whom we all admire and respect, and who is one of our Honorary Members, was about to contribute a paper to our Transactions, I was delighted, because I said to myself, at last we are going to have the facts about triple-screw ships. Now I ask anyone to read this paper, and say if that is so. The two triple-screw ships—I believe

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there are two in the United States Navy; there may be more, but I have not heard of them—have now been some years in service. They have been available for experiments. It is quite possible that experiments have been made, but we have not any results of those experiments here, therefore we cannot discuss the question on the basis of recorded experimental performances. Now, in the analysis of steamship efficiency we want more than is indicated here.

Admiral Melville says that in the preparation of a set of tables showing the power required to drive a vessel of a given displacement at a given speed, data have been used which were gathered from the results of about two hundred trials of nearly as many ships. It would be interesting to know how many of those were triple-screw ships. It is certain, of course, there can be only two out of two hundred where the author has the facts from his own experience. I think I have a fairly complete acquaintance with the trials of the triple-screw ships which have been so far built. If they were all put together it would be found that they made up a very small proportion of the two hundred. I regret that Admiral Melville is not here to tell me whether that is the truth, and whether it is not a fair deduction to say that such broad conclusions as are drawn on page 5 of this paper, as to the relative efficiency of triple and twin screws, rest on a somewhat slender basis.

I stand in a very difficult position in another way. It is this: I know a great deal more than I can say. It is not often that one is troubled in that way, perhaps, but in this case it is so. I have very exact information of the most scientific character, not merely of the performances of triple-screw ships, but of the comparison of such performances with model experiments, and I cannot (I wish it were otherwise) at this stage furnish the facts that are in my possession to the Institution, because they were given to me under the condition that they were to be for my personal information only. I must therefore confine myself to the paper. Taking the paper, what is said? First: that the use of triple screws leads to a considerable economy at high speed as compared with twin screws. I know of no conclusive

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facts establishing that contention. Second: Admiral Melville recommends a third arrangement of triple screws. The first arrangement was with the screws of fairly equal size; the second, which has been boldly tried in Russia, where they have the courage of their opinions, was to have a very small screw in the center and two large screws at the side. Is it not a suggestive circumstance, gentlemen, that, trials having taken place with those two arrangements, we are now introduced to a third one, which puts the large screw at the center and the small screws at the side? I am asking for information. I do not know, but I say is it not suggestive? Then, again, the only fact of a numerical character that I find in this paper refers to the work involved in revolving the screws of a 12,000-ton triple-screw ship. Clearly, that is not an American ship, because there are only two triple-screw ships in the United States Navy, and they are, I believe, under 7,500 tons. Could we be favored with any statement of what this anonymous ship is, and how far these experiments went, or whether this is an estimate of power? Of course very much turns on questions of this nature.

Now, I would like to go further. Triple screws are recommended on the ground that they are a necessity under certain circumstances, and a particular example is given us of a ship which, I believe, is to be of 24 feet draught and 12,000 tons—I do not understand that she exists—and to be 22 knots speed. Now, what I have to say, with some knowledge of the subject, is that I should be quite prepared to undertake to produce a most efficient twin-screw ship to develop that power on that draught; so that, speaking with some experience, I say that that is not an example of the case which may arise—I always said it may arise. I foresee conditions under which it may arise, when we shall have to go on from twin screws to triples; but I do not think the example chosen by Admiral Melville is one where the necessity for more than two screws does arise. In fact, I may say that we are going to do very soon the very thing under discussion in a twin-screw ship.

There are various statements made in the paper which one cannot follow in detail, but which seem to me to indicate that

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Admiral Melville has not that complete acquaintance with model experiments which we on this side possess. He speaks, for example, in a somewhat slighting manner of the information to be derived from experiments with model screws. If I may be permitted to speak with some authority, as I trust on this matter I do, I say that we are under the greatest obligations to model-screw experiments for our guidance in efficiently utilizing the large powers to which we have attained. And I will go further, and say that, on some occasions when, in order to experiment in the ship, which we always do—and, of course, I quite agree with Admiral Melville that the ship experiment is the crucial one—in some cases where, in order to get varying experiments, we have in one ship of a class put in our model experimental screw, and in another ship of the class put in a variant on that, we have often found it desirable to come back to the model experimental screw. So that I would like to record my opinion (which I am sure Admiral Melville will take in good part) that if he had a closer acquaintance with the application of model experiments to screws he would have much higher regard and respect for the results.

With regard to the remarks in the paper on the utilization of the frictional wake and the effect of shortening the shafts of the side screws, it appears to me the writer is only discussing tendencies; but it is necessary to ascertain the aggregate result of such changes on propulsion, not mere tendencies. It is a very interesting example of that to recall that the elder Mr. Froude, in his earlier work, as will be seen by a reference to the Transactions, favored very much the putting the single screws, which were then the common propellers, far abaft the hull of the ship, in order to diminish the augment of resistance; but, when experiments were made with screws as well as models, it was found that the balance of advantage did not lie that way.

As to the attitude of the Admiralty towards triple screws, I intend to say nothing except this, that, so far as I represent the Admiralty, the case was fairly stated two or three years ago in a book for which I am responsible, and anybody can read it for himself. He will find that, up to date, the decision has been

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based on quite the conditions which Admiral Melville supposes. The question of draught has not been, and is not, the most important one to consider.

I should like, too, to have seen in the paper a more exact statement of what is involved in regard to internal space occupied, not merely by engine rooms, but by the shafting and the shaft passages in triple-screw and twin-screw ships. I can say this: that in vessels which carry the armament and the supplies of ammunition which those of the Royal Navy do, it would not be found a very easy thing to get a good stowage of ammunition in the after part of a triple-screw ship of the dimensions contemplated in the paper, and with three shaft passages running through in the finer part of the after body. In the Royal Navy it is the practice to endeavor to fairly equally distribute the ammunition at the two ends of the ship. We attach some importance to that in the consideration of armaments. These are considerations which press upon the designer of a warship: the best appropriation of the internal space is a most important matter, as Sir Edward Reed and everyone who has had to do with warship design will know; so that to discuss this matter from the point of view of propulsive efficiency only, would be to discuss it partially. One wants to look all around these matters.

I trust that in nothing I have said I shall have appeared to have been in the least forgetful of our obligations to Admiral Melville for giving us this paper. I have endeavored to point out that from the scientific and professional point of view it is not the sort of information we require to deal with this subject in a clear and conclusive manner. If he has that information, and is at liberty to give it to us, we should all be delighted and we should be under the greatest oligation to him. We certainly must look forward to higher speeds. We have to accept limitations of draught, and the time may well come—I have always thought that it may come, unless we change in a more radical fashion—when, if we persist in our present propelling arrangements and our present forms of propeller and types of machinery for certain classes of ships, triple or multiple screws will become the rule. But we are dealing with things as they stand up to

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date, and my conviction is that no case has been made out in this paper for the alleged superior efficiency as propelling instuments of triple screws under the conditions prevailing in first-class battleships or large cruisers at high speed.

Mr. George Quick, Fleet Engineer, R. N., retired (Visitor): I have the misfortune to be merely a sea-going engineer. I have never built a ship or an engine, but I have had a great deal to do with both at sea. I have read a great deal of history, and the one lesson I have learned from it is that all the personnel and material of our navy should be organized for the supreme hour of battle and the week afterwards. I look upon our marine engines as fighting weapons, and not as mere economical machines to obtain the greatest amount of power out of every pound of coal. And I cannot help thinking that we shall have to adopt triple propellers for all our larger ships if we are to hold our own with other naval powers in actual warfare. Let us take the case of a twin-screw ship proceeding to China or any other distant station. During her passage out war has been declared, and one engine breaks down; then that ship cannot go into battle with a single screw only, for she would not possess sufficient speed, nor could she be steered well enough to take her place in line of battle. It would not matter what the power of that ship might be, we dare not take her into battle with only one propeller and one set of engines. Now, take the case of the triple-screw ship. She goes out to China or the Pacific, using her middle engines and middle propeller only, keeping her wing engines at rest and in perfect order. On her arrival she finds war has been declared, and serious defects are found in her middle engines, so that they are disabled, and would take some weeks to repair. But that vessel could go into action with her two wing screws. She would be practically a twin-screw ship, in perfect order, but of reduced speed, yet certainly fit for the line of battle. But, even if the passage had to be made at high speed, using all three propellers, the probability of safety is far greater with three screws and three sets of engines than with only two propellers and two engines.

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I differ a little from Admiral Melville about the use of the screws. I should be disposed to work the middle screw only in cruising or in making ordinary passages, and should reserve the two wing engines and screws for going into battle, instead of working the wing screws for ordinary cruising. I wrote a paper on this subject in 1875, which was read at the Royal United Service Institution, in which I stated "that I did not consider that even twin screws gave that security for the propelling power which is now required by the exigencies of modern naval warfare." The watch-keeping naval engineer knows how easily an engine may be disabled in action. A splinter from a shell, or a broken bolt falls into one of our engines and it is disabled, and then, if the ship has only two screws, she becomes like a man with only one leg. But if the ship has three sets of engines and three propellers, and one of them is damaged in action, there are still left two sets, which would give very effective propelling power and steering efficiency under all conditions.

I agree with Admiral Melville that the middle engines should be more powerful than either of the wing engines, but scarcely to the extent he suggests. In the case of a triple-screw ship of 30,000 I.H.P., I should prefer to give 12,000 I.H.P. to the middle screw, and 9,000 I.H.P. to each of the wing screws. I feel indebted to Admiral Melville for his remarkably fair, clear and explicit statement of the case for and against the triple propellers. He has been a very busy man of late; he has had but a very small staff. He has been much overworked by the war, so that if there are any omissions in his paper I think we must put that down to the immense amount of work he has had; and, furthermore, I know that he was ill for some time lately. It is also quite possible that he does not consider himself to be at liberty to give further information than that which he has given us. We all fully recognize the tremendous work of the staff at our own Admiralty during the last year or two, although we have had no naval war, so I think we must also remember the strain on Admiral Melville's department if there be any shortcomings in his paper.

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Lieutenant H. P. Norton, U. S. Navy (Member): My Lord and Gentlemen, I cannot make a full reply, but I would like to answer some of the points. This paper having been written by the Admiral, and I having been detached from duty in his Bureau before he commenced it, I do not know all the circumstances which have led up to its preparation; but I do know from his letter to me that every fact he has stated he has authority for, and if the Council will ask him, I am sure, if he is at liberty, he will add it to the discussion of what has taken place here to-day.

If you remember, we had triple-screw ships and twin-screw ships in commission during our late trouble, and, as mentioned in the paper, during the battle of Santiago our two fastest ships were practically of ordinary speed, because they could not stop to couple up the two spare engines. The problem is this: We have a ship, and we want to make 22 or 24 or 25 knots. She may make that two or three times during her commission—most of her cruising will be done at an average speed of 16 or 17 knots—but, if we can get a ship which is economical at 16 or 17 knots, we do not care what it costs to make the 24 knots. This is what this calculation is based on. We are now designing at home some of the largest battleships and cruisers of any navy, and this paper is the result of the calculations that have been made at the Bureau of Engineering for the propelling machinery of these ships. They are to be three-screwed ships using five-cylinder quadruple-expansion engines for the center screw, and four cylinders for the wing screws, the wing screws to be used together, or the center screw, and, whichever you are using, you can obtain 16 or 17 knots, and when you want the maximum speed you get it, and do not care what it costs.

I know a great many trials have been made with the *Columbia* and the *Minneapolis*, although I have not the data here with me; but I am quite sure it will be furnished when the Council ask for it. That is what has governed the Admiral in submitting this paper, and probably, had he anticipated the form the discussion has taken, he would have put the facts in. Regarding the question of electrical machinery, we went very heavily into that on the *Brooklyn*, and, as the result of her trials in the

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Spanish war, we have decided not to duplicate it. You can tell what is the matter with a steam or hydraulic engine instantly; but you may chase for hours to find a broken circuit, and by that time the action is over, and you are out of the deal.

Sir William White: Is it not the fact that electrical power has been largely used for ordnance working?

Lieutenant Norton: Yes; but it is not to be used in the turrets, or the ordnance work of any of these ships, except for the hoist. That is the result of the fighting on the *Iowa* and the *Brooklyn*. Speaking of economy, the only question of economy in the engine forces which has been considered has been when working at ordinary cruising speeds. We do not anticipate an economical ship at both the maximum and the cruising speeds; we do not know how that can be obtained, but we should be glad to do it if we could.

About the couplings, we have no trouble in coupling up when the ship is going 17 or 18 knots. By means of a friction brake the screw can be held without any difficulty until the coupling bolts are fitted, as was done on board the *Minneapolis* when she was supposed to be chasing the Spanish fleet. As regards the two-bladed screws, as I understand the question, if you are going to propel the ship with a two-bladed screw, you have to have the same area as you would with three blades, and, as it is not the intention to secure the propeller when not in use, the frictional resistance would be the same whether the area is in two blades or three. There is no advantage in using the two blades unless you secure the propeller in the deadwood, which is not the intention in these vessels. I do not feel quite qualified to answer the other remarks.

The **President** (the Right Hon. the Earl of Hopetoun, G.C.M.G.): I feel certain, gentlemen, you will desire that the Secretary be authorized to convey a cordial vote of thanks to the Admiral for his admirable paper, and I think our thanks are also due to Lieutenant Norton for the excellent manner in which he has read the paper and in which he has replied.

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The following communication was received from **Mr. S. W. Barnaby** (Member of Council):

I wish to say how much I appreciate this suggestive and valuable paper. Many years ago I expressed surprise that triple screws had not come more into favor for high-powered ships of war. It seems to me that the arrangement proposed by Admiral Melville has many advantages. Perhaps the most obvious is that upon which stress was laid in the paper, that is, that it fitted the ship, and if also it proved in practice to be the most economical disposition for cruising purposes, as Admiral Melville assured them that it did, then it seems difficult to resist the conclusion that the most logical arrangement of the motive power of warships is that proposed in the paper. The only thing to be said against the argument that greater efficiency of propulsion followed from the use of three screws because more advantage is taken of the beneficial influence of the frictional wake in reducing slip than is the case with twin screws, is that it would seem to lead to the conclusion that a single screw should be more efficient than twin screws for the same reason, and this did not appear to be borne out by experience.

I am more disposed to lay stress upon the reduction of weight and improved economy at low powers made possible by their adoption than upon the probability of an improvement in propulsive efficiency attending the use of triple screws. Admiral Melville stated that in a ship of 12,000 tons, 22 knots and 23,000 I.H.P., having three equal screws, the power required to drag one disconnected screw amounted to 150 I.H.P. at 10 knots, and to 600 I.H.P. at 15 knots. When the middle screw is designed for half the power the resistance offered by it to being dragged through the water must be still greater, not only on account of its greater size, but also, I think, because the pitch rate would be finer, and I suggest that it might be worth while to consider whether it would not be found more economical to use one of the auxiliary engines, say a circulating-pump engine, made especially large for the purpose, to turn the center propeller at a rate of revolution corresponding to the speed of the ship, as it should take considerably less than 600 I.H.P. at 15 knots, and

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less than 150 I.H.P. at 10 knots, to overcome the friction of the disconnected shaft and propeller. I suggest a circulating-pump engine for the purpose, because it could be conveniently placed at the after end of the engine room, near the shaft coupling. The center centrifugal-pump engine might be arranged either to drive the pump or the shaft, as required; but it seems to me that it would probably be most economical to enlarge one of the wing circulating engines, and thus avoid the friction and other wastes involved in the running of the third circulating engine.

The following reply to the discussion has been received from **Rear Admiral Melville.**

I note that the principal desire expressed by the members of the Institution in regard to this paper is for more data. I fully appreciate the position of Sir William White regarding data which he is unable to publish. In fact, much of the information used by me in the preparation of this article is such as I feel unwilling to make public. I am, however, at liberty to give the results obtained from a consideration of the data, and I have done so. I realize that a considerable amount of detailed information which was omitted might have been included in the article. This omission was caused largely by my desire that the paper should not be too long for ready presentation before the Institution of Naval Architects. It was caused also by the fact that the number of trials from which the conclusions were drawn, something over two-hundred, was considered too small upon which to base any absolutely accurate figures, although establishing fully the general law. On that account such figures as have been included in my paper have been specifically stated to be tentative. They are subject to alteration as a result of future experiment.

I have attempted so carefully to avoid any exaggeration of the advantages of triple screws, that I think the figures enumerating the economic gains due to their use, both for high and low powers, will be found greater rather than less than those given in my paper. In deference, however, to the expressed desire of the Institution, I submit such data regarding the performance

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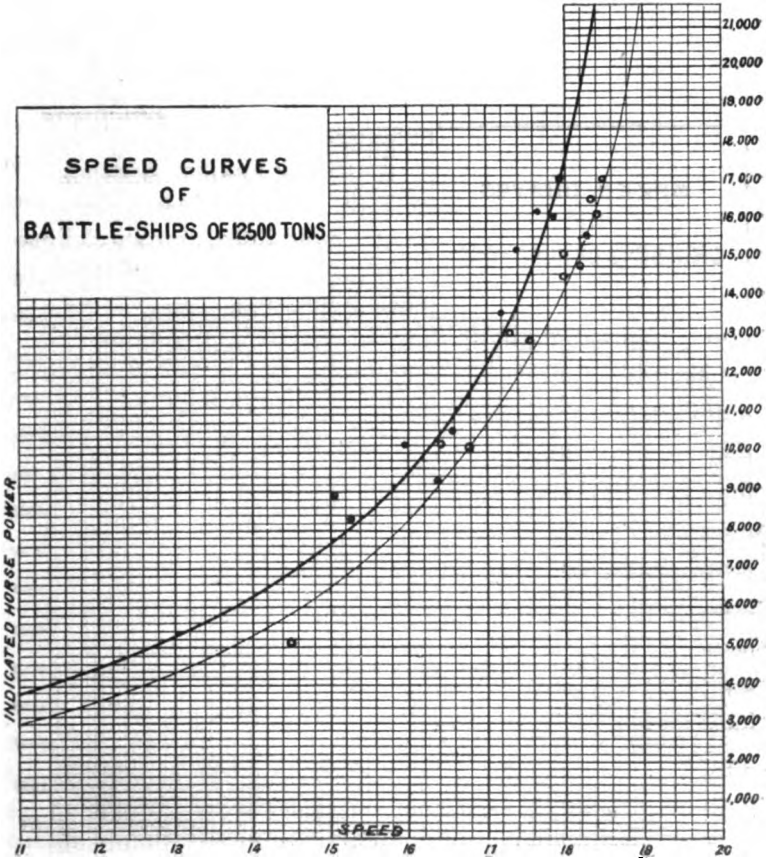

THE UPPER (HEAVY LINE) CURVE FOR TWIN-SCREW BATTLESHIPS.
THE LOWER (LIGHT LINE) CURVE FOR TRIPLE-SCREW BATTLESHIPS.

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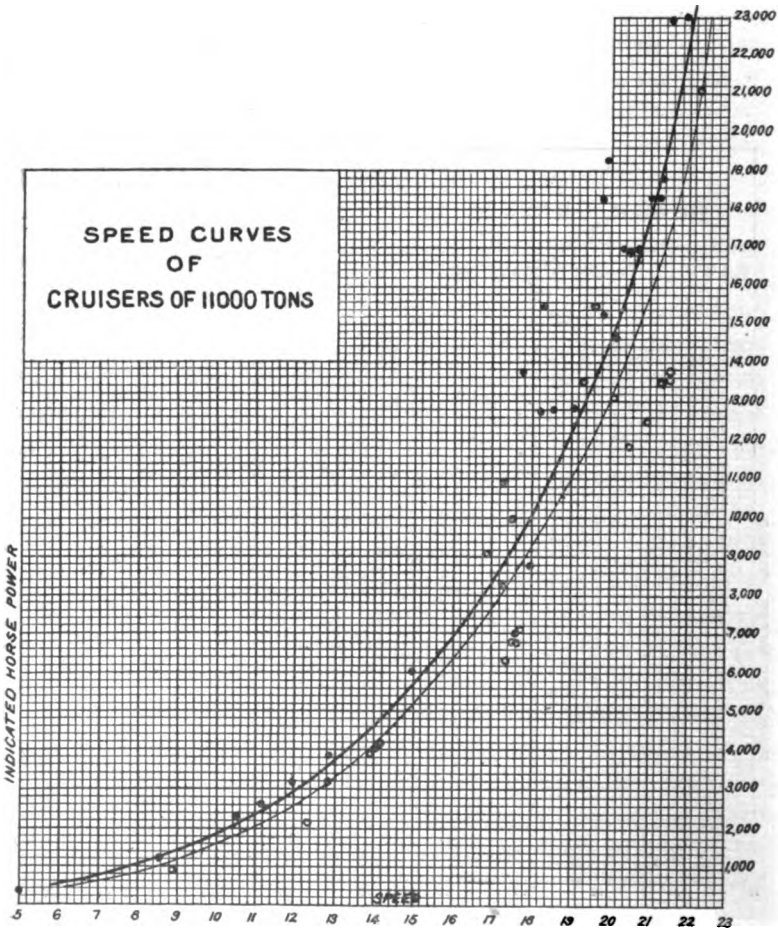

THE UPPER (HEAVY LINE) CURVE FOR TWIN-SCREW CRUISERS.
THE LOWER (LIGHT LINE) CURVE FOR TRIPLE-SCREW CRUISERS.

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of triple-screw ships as may be communicated without breach of a public trust. In this connection let me remark that I regret very much that Sir William White finds himself unable to give us the benefits of such model experiments as he may have made with triple screws. While I believe that no tests of propellers are so valuable as those obtained from the propellers themselves, in position on ships, where the theoretical conditions are thus minimized, and where we have to deal only with full loads and with service conditions, I am sure that it would be very interesting to compare these results with those obtained from tank experiments. It appears to me that such comparison would be a good test of the accuracy of model trials.

I append a speed and power curve of certain battleships reduced to 12,500 tons displacement by Froude's well-known laws of comparison, giving a separate curve to those ships fitted with triple screws. All trials from which these curves were constructed are of ships of approximately the same size, none of them being of less than 10,000 tons displacement. All belong to the same navy; they have the same character of hull and the same general under-water body. They are, in fact, almost identical in all respects, with the exception of the propelling machinery, and of the slight modifications in the under-water body necessary from the introduction of a central screw in the ships so fitted. Consideration of these curves will show at once that the power required is, in all cases, high in proportion to the speed. This is due to the peculiar character of the hulls in all of the ships considered. It is to be noted, however, that these characteristics obtain in the cases of the triple-screw battleships as well as in those fitted with a twin-screw system. The points marked by small circles and dots, respectively, are obtained from actual trials, and include the power of the auxiliary machinery.

I append also a speed and power curve of cruisers reduced to 11,000 tons displacement by the same laws of comparison. While these vessels are not so homogeneous in type as the battleships cited, it will be noted that there is with them about the same gain for the triple-screw system in the power required to attain a given speed. This difference is somewhat

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greater than that which I have given in my paper as the probable advantage to be derived from the use of triple screws. Each point is from the actual trial of some cruiser, although they are not all from the same navy. Only a part of these trials includes the power of the auxiliary machinery. It appears to me that these curves, drawn as they are to give the fullest advantage to the system of twin-screw propulsion, develop fully the superior efficiency of the triple-screw system for full-power trials; or, indeed, wherever all engines are in use. However, as Sir William White says, the matter of the propulsive efficiency of the propellers is but one of the desiderata to be sought in the design of a naval vessel. I submit, however, that the superior propulsive efficiency of triple screws is an element of considerable advantage in their favor, although it must by no means be considered the deciding one. The deciding point in this matter seems to me to be the fact that naval vessels do at least 90 per cent. of their cruising at speeds below sixteen knots. In vessels of the fast type now so universally prevalent the condensation in the low-pressure cylinders is enormous when the ships are making these low speeds.

Mr. Barnaby has pointed out that the greater efficiency of propulsion incidental to the use of three screws, and consequent upon the utilization of the following wake, would apparently imply that a single propeller is more efficient than are twin screws. I have stated that up to a certain speed I consider that a single screw is most economical. Beyond that speed it is necessary to increase the size of this screw so greatly that the efficiency of the propeller is considerably reduced on account of the increased friction, and also on account of the increased difficulty of securing a free run of water to the blades. I am not sure when the critical point is passed. In the light of experience, however, it would seem that for ships having a maximum speed of as much as 15 knots the advantages due to the division of the propelling instrument into two screws are more than equivalent to the loss due to working these screws in the less advantageous position under the quarters of the ship. This may explain why twin screws are in many cases more efficient

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than single screws. The use of triple screws, however, includes not only the advantages due to the use of smaller screws, but also the advantage due to the following wake. Triple screws must, therefore, always be more efficient than twin screws.

Data concerning the cruising efficiency of ships fitted with triple screws have been obtained from various sources. Tests of the steam consumption of the main and auxiliary engines of the triple-screw cruiser *Minneapolis* have been made. Trials have been made of this and other ships working with one, two and three screws at (A) constant speed; (B) constant power; (C) with a fixed coal consumption. Trials have been made of the *Kaiserin Augusta* (the details of which have been published) with and without a dragging screw. We have made trials of the *Minneapolis* at a constant speed and have measured the speed of rotation of the central screw (A) when revolving freely and (B) when connected with the central engine. Several twin-screw ships have been tried with one engine, with a resultant gain in coal consumption at the lower speeds when not only was there a heavy drag from the idle screw but also there was a considerable rudder resistance. Trials have been made of the *Kaiserin Augusta* working with one engine, (A) with the center engine and (B) with one of the wing engines, in either case the other screws being left to revolve freely. The difference in power required to attain a fixed speed in the last trials measured the resistance of the rudder.

The trials of the *Kaiserin Augusta*, which were conducted with great thoroughness, measured accurately the drag of the screw and also the resistance of the rudder; the latter being, at a speed of 14.1 knots, considerably more than twice as great as the drag of two idle screws when one of the wing engines was used alone. These trials developed fully the further fact that there is not sufficient propeller area in the central screw (the three screws being equal) to drive the ship economically at a speed greater than 9 knots. Trials of the *Minneapolis* were made with a constant coal consumption and working with both one and two engines and with absolutely the same auxiliaries in use in both cases. It had been found that the condensation in an engine

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was approximately a constant, irrespective of the power developed, this condensation increasing slightly for the lowest powers. On these trials, with a fixed coal consumption, with two engines in use, 938 H.P. were developed, giving the ship a speed of 9.53 knots. With one engine only in use there was sufficient steam to give 1,236 H.P., though the speed of the ship did not exceed 9.36 knots. Knowing from previous experiments exactly the steam consumption per horsepower of these engines, it was possible to ascertain accurately the condensation, which was found to be, as has been stated in my paper, about one pound of water per horsepower of the maximum power of the engine.

The resistance of a dragging screw was measured in the experiments of the *Kaiserin Augusta*. It, as well as the engine friction, was also obtained on the *Minneapolis* in the following manner: The number of revolutions of the central engine when coupled with and turned by its dragging screw was observed accurately for a fixed speed of the ship, and also the number of revolutions of this screw for the same speed of the ship and when uncoupled from the central engine. The power developed by the propelling engines (the two-wing engines) was observed for the two conditions, and the difference between these powers measured the unloaded engine friction of the center engine. Further, on the assumption that the resistance of the dragging screw varied as the square of the difference between the number of revolutions made by it and the number of revolutions which would give it a zero slip, there was obtained the ratio between the resistance of the screw and the resistance of the engine and screw combined. The resistance of the dragging screw, ascertained in this manner, agreed very closely with that obtained from the results of experiments on the *Kaiserin Augusta*. It is of importance to note that the unloaded engine friction of the central engine was, at a speed of 10 knots, considerably greater than the drag of the central screw when the latter was left to revolve freely. If it be granted that the engine friction varies as the power of the engine (this is only an approximation of the correct rule), it is evident from the above that the horsepower required to attain a speed of 10 knots is greater with two en-

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gines than it would be with one, if the latter has sufficient propeller area to avoid excessive slip. This is quite apart from the saving due to the decreased condensation of the engines. In fact, the *Minneapolis* ran at the rate of 9.73 knots with 1,872.6 H.P., and with one engine, while with two engines, to make a speed of 9.71 knots, she required 1,940.94 H.P. On the other hand, however, the speed of the *Kaiserin Augusta* was 9 knots with two engines developing 932 H.P., while for a speed of 9.07 knots with one engine 1,050 H.P. was required.

As I have said, in order that one engine alone may work properly, it is necessary that the propeller should be of sufficient disc area, which is not the case when the propeller is designed to transmit but one-third of the full power, and it is to this cause that I attribute the above comparatively unfavorable results. Experience with twin-screw ships has shown that propellers having a disc area of one-half that which is necessary to drive a vessel at a full speed of as much as 20 knots are efficient at ordinary cruising speeds. It appears to me that these results form a very strong argument against the use of a small central engine for cruising purposes.

The figures set forth in my paper as to the power absorbed in the drag of the screw are the maximum; those given as to the gains due to the use of triple screws under cruising conditions are minimized. Instead of stretching the case in favor of three screws, I believe I have done rather the reverse. I have been careful to give the established twin-screw practice the benefit of every doubt, which, I think, is quite proper. There are, however, a great many points in favor of the triple-screw system which are touched upon in my article and which have not been controverted in the least. I cannot say that I recommend the installation of triple screws in all naval vessels; but wherever as much as one-half the total power is sufficient to obtain a speed of, say, 16 knots, that system appears to me to be the only logical one to install.

The weight and cost of the machinery in a triple-screw ship is certainly no greater than for large twin-screw machinery of the same power. It is possible, as was shown off Santiago in

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the case of the *Minneapolis*, to couple up, without damage, the central screw of a triple-screw ship while the vessel has a speed of 18 knots. This was actually done, and is an instance of the great tactical advantage possessed by triple screws over the method of arranging two engines on the same shaft—a system which our recent war experience will probably prevent us from installing in any future naval vessels.

In the discussion of my paper attention has been called to the engines not ordinarily in use under cruising conditions with triple-screw practice. I desire to call attention again to the fact that there is quite as much power not in use in twin-screw practice for the same ship and speed. Further, the idle power in triple-screw practice is maintained in much more efficient condition while cruising, and this with considerably more ease than obtains if all the machinery is in motion. The matter of the short lengths of shafting outside the ship with triple screws is one to which, I think, not sufficient attention has been paid. It would avoid the necessity for the 70-feet propeller shafts which, I believe, are now being used.

As to the space gained by the arrangement of triple-screw machinery proposed by me in this paper, I may say that, in a design now being prepared, it is found that the use of a large central engine and two small engines saves enough space below the protective deck from that required for twin-screw machinery to instal the evaporating plant of this ship and to provide for a pump-room. In Plate (see page 656, cross-section only) will be found a sketch of this design. It will be noticed that the central engine is a five-cylinder engine. This is intended to be used only in connection with the wing engines, and when the maximum power is to be developed. The wing engines are four-cylinder engines, and it is expected that these will be used during ordinary cruising. The number of cylinders ordinarily in use will therefore be but eight. No difficulty has been experienced in securing sufficient ammunition rooms, &c. The most serious problem has probably been the installation of the steering gear. The United States Navy had a twin-screw ship in 1862, the *Forbes*, and for river service in the Civil War had a great many multiple-

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screw ships, called at the time "tin-clads." There was also the *Agamenticus* class of twin-screw monitors, constructed in 1863 for our Navy. These were four ships of something over 3,000 tons, and one of them visited the Thames something over thirty years ago. This was some time before Sir William White first advocated the use of twin screws in the British Navy.

The scheme proposed by Mr. Barnaby for working the central shaft by means of a circulating-pump engine would probably lead to a slight economical gain, on the principle that the engine efficiency will probably be greater than the efficiency of the dragging screw. I think, however, that the introduction of this feature will not lead to any very great saving, and it might interfere with quickly connecting up the central engine, at the commencement of chase, for instance. This is a detail, however, which further experience may, very possibly, show to be worthy of installation and of use, at least during ordinary cruising.

I am pleased to note that Sir William White says that a continuation of progress in design along present lines may lead to triple or other multiple screws being introduced into the British Navy. I believe that we have already arrived at the point where triple screws are considered necessary. In conclusion, I desire to thank the Institution for the discussion of this paper. I regard intelligent criticism, whether favorable or the reverse, as of much value in bringing out the points of any matter at issue.

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OBJECT LESSONS.—THE LENS AND PENCIL IN MECHANICAL ENGINEERING.

By Lieutenant Commander A. B. Willits, U. S. Navy.

The illustration given in the May number of the Journal (page 446) of the results of galvanic action on a cast-iron propeller hub, where the blades and cone were of composition and the hull of the vessel itself copper sheathed, was an object lesson which needed but few added words of explanation, and readily fixed itself in the mind of the engineer glancing over the figure.

The force of a lesson of this character is greatly qualified by the amount of time it requires of the reader to comprehend it, and consequently, in these busy times in the mechanical world, where the rushing tide of progress is forever casting upon the shore all the inert elements of the crowd with which it teems, there is the greatest need of curtailing the elaborations of drawings and illustrations, and of reducing to the shortest possible amount the period necessary for a complete understanding.

In an original mechanical design or in a "lay out" for a machinery plant, the usual multiple drawings in plan, section and elevations must continue to hold their position of imperative importance. When, however, it comes to the matter of representing mechanical objects already existing, in order either to describe them or to call attention to defects, breakdowns or repairs, then a free-hand sketch, an isometric illustration, or a good photograph will be found to be far ahead of the "plan, section and elevation" in nine cases out of ten, both as regards expeditious production and ease of comprehension. Lengthy verbal descriptions are thereby also greatly curtailed and the danger of *pigeon-holing* much reduced.

The most progressive engineers "talk with their pencil," and when a clear mental picture is possessed by a good mechanic of

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the object he desires to describe, the ability to make a quick and comprehensive sketch is not difficult to acquire and rapidly increases with practice. Unfortunately, too few persist in this exercise, so that instead of the possible reports of defects being rendered clear and easily *read* by a picture, we continue to receive long-winded descriptions " with attached blueprints," the latter often indicating laborious work on the tracing from which it was made, and not seldom being of a subject only requiring an exterior view to thoroughly elucidate.

In presenting the few object lessons selected for this brief article the work of the lens is employed in illustrating two of the subjects, and is of particular interest in view of the rapid growth of the use of the camera in mechanical engineering. This very truthful instrument has a superhumanly keen eye for exteriors and prospectively, with the X-ray adaptation, for much now hidden from view. When properly handled it can well serve to produce many working "drawings" (bar the word) even while showing a simple picture, as dimensions can be as readily marked on photographic negatives, and printed therefrom, as upon blue prints taken from such negatives. In marking on the negative proper any good opaque can be used, preferably upon the negative face, marking the figures backwards. Unless the negative is upon a celluloid film, marks upon the glass or back of the negative will not print clearly. With care in this work, requiring very little skill or time, a photograph can be made many times more useful than it generally is, and for repair work, where it is necessary to forward drawings showing the defects and requirements for new parts, a photograph will frequently be found most valuable. Much unfavorable comment and adverse criticism upon photography in engineering results from the misuse of the camera and the desire on the part of the operator to devote the principal portion of his work to the artistic instead of the useful; hence we have photographs of boilers of novel form, wherein, instead of the principal features with dimensions being included, the main object in view is the head of some boiler maker projecting from the manhole, or the superintendent of the boiler works in the

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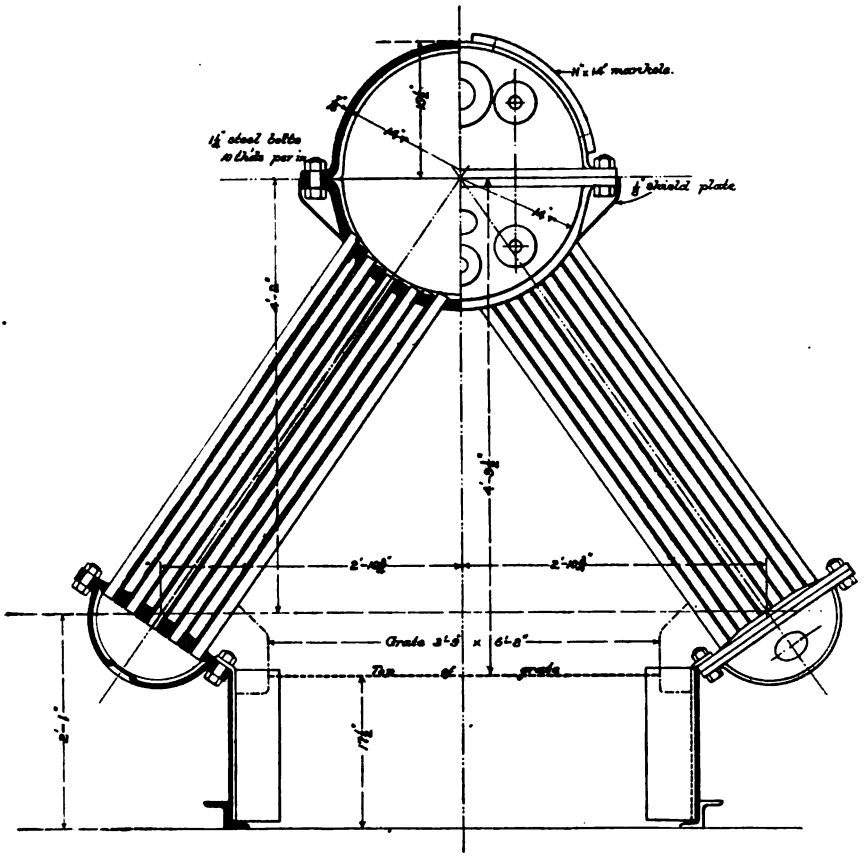

FIG. 1.

foreground with the boiler as an incident in the rear. To use the camera properly here, the principal object must be that of conveying useful information. With this in mind there is nothing more really helpful or any process that will repay the engineer better in its results.

The first figures (1 and 2) represent a section of a Yarrow boiler and a bulging of the upper part of the steam drum of the same, which latter occurrence took place during a recent voyage of one of our naval ships, the discovery of the bulge being only made after the ship came to anchor. In this case the close

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approach to a serious accident is readily seen by inspection of the section of the drum in Fig. 2. These bulges occurred undoubtedly through a collection of soot upon these points taking fire and burning with sufficient intensity to overheat the shell. The coal used was of very inferior quality and undoubtedly lent itself readily to such an accident. The mishap, however, points most graphically to the necessity of protecting the upper parts of these drums from the possible collection of soot upon the metal. It is understood that this is now always done with the Yarrow boilers, but in the present case no protection had been

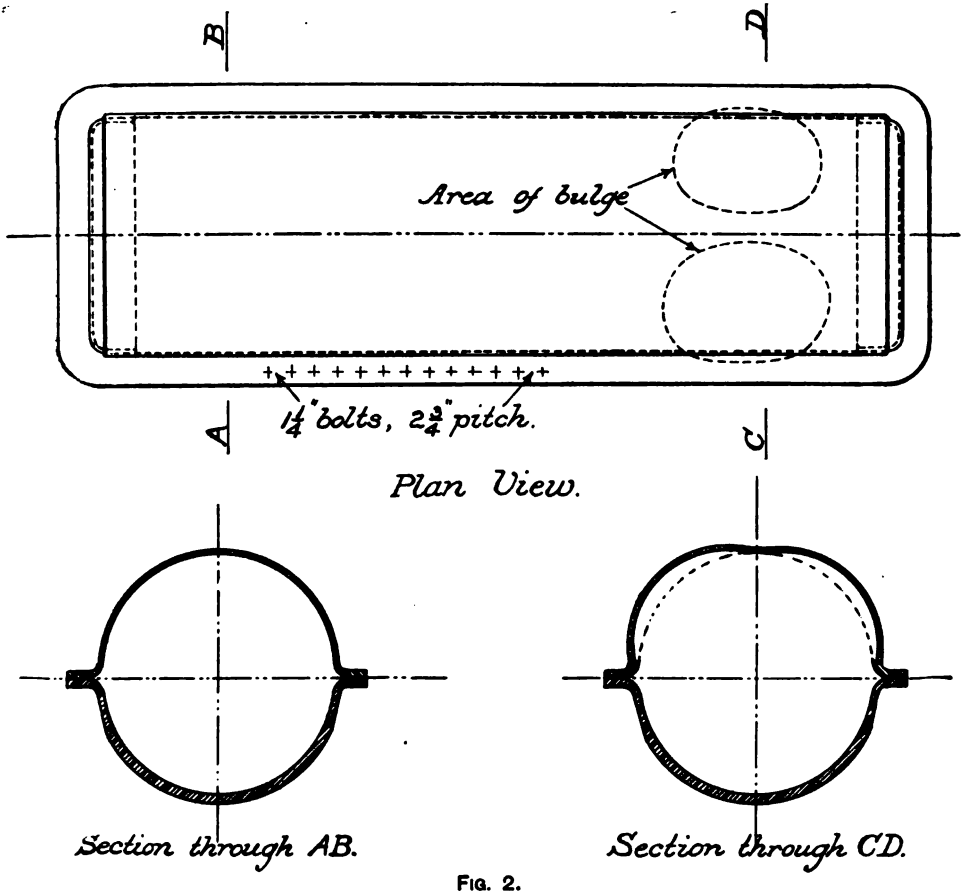

FIG. 2.

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afforded. The steam pressure was about 200 pounds, and the metal at this section was so greatly overheated as to permit the expansion as shown over a considerable area and an opening of the inside portion of the flanges in the wake of the bulges. As it appeared that the metal itself was not seriously injured, efficient repairs were made by removing the flange bolts, one by one, opposite the bulges and reaming out the holes parallel, fitting in larger bolts with nuts on the upper end of at least one-half inch greater depth than the standard nuts. A cross slot cut in the top of the nut for the use of a heavy steel screw-driver wrench made the proper setting-up easy to accomplish in place. The top of the drum was then protected by a non-conducting material, and a deflecting plate for the gases fitted in the uptake. "Smooth-on" compound was put in the opened portion of the flanges on the inside, a suitable manhole plate in these drums rendering the work comparatively easy and the results eminently satisfactory for present use.

The allusion to a close approach to the danger line in the above "accident" (if it may be so called) brings to mind the condition of a 7-inch copper auxiliary steam pipe recently removed from one of our battleships. In illustrating this (Fig. 3) the camera has shown the condition far more graphically than right-line sketches possibly could. Numerous surface cracks, some of them very deep, were discovered in this copper pipe, and while a steam pressure of 160 pounds had been carried during the service of the same, a test application of 180 pounds hydraulic pressure burst the pipe. This pipe was supposed to be of excellent quality and was of No. 5 B.W.G., but the actual condition points to the necessity of the very closest inspection of all material used for pressure parts after the same has been formed into the shape desired.

From this figure one can readily realize how much a photograph of the steam drum defect (Fig. 2) taken from a proper position would have added to the explanation of the situation. This would have shown the bulges, bolts and general arrangement, but, owing to the confined space, as is frequently the case with machinery, it would have been difficult to secure.

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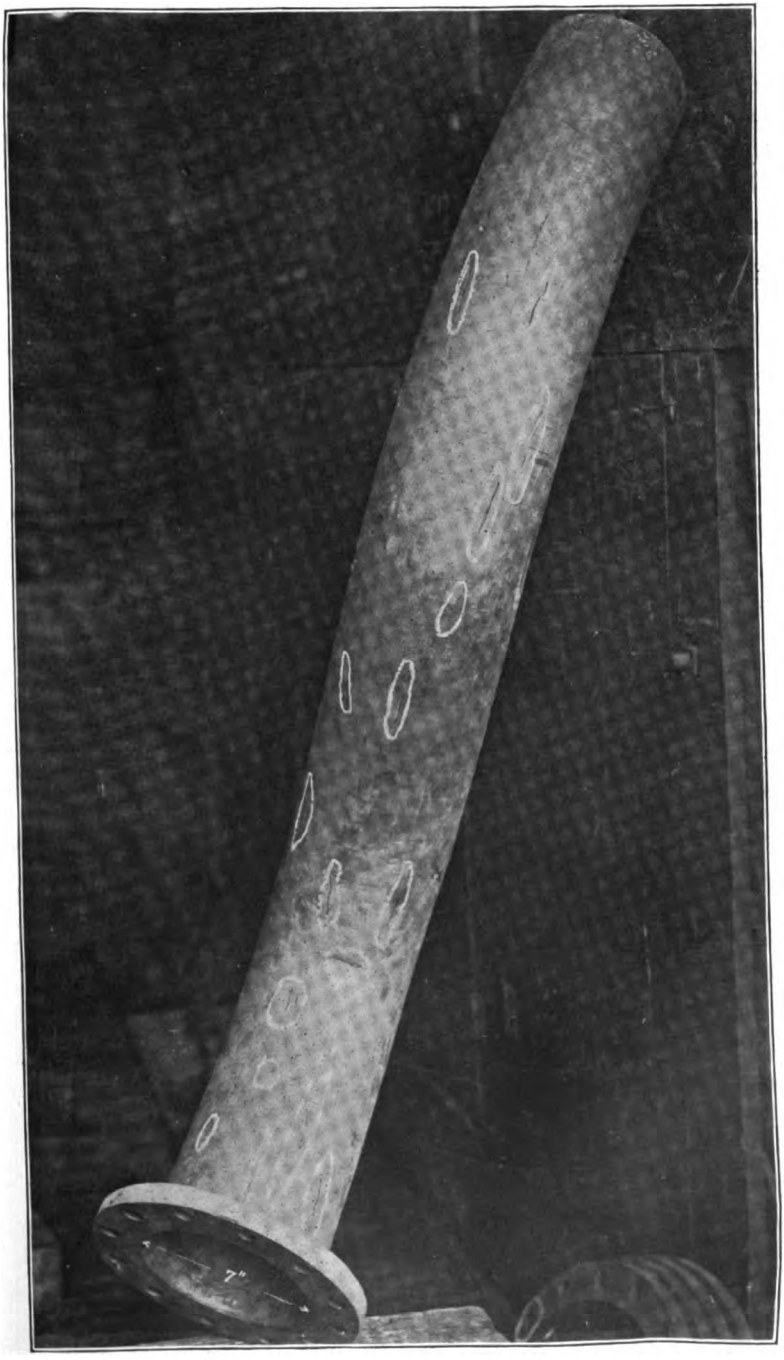

FIG. 3.

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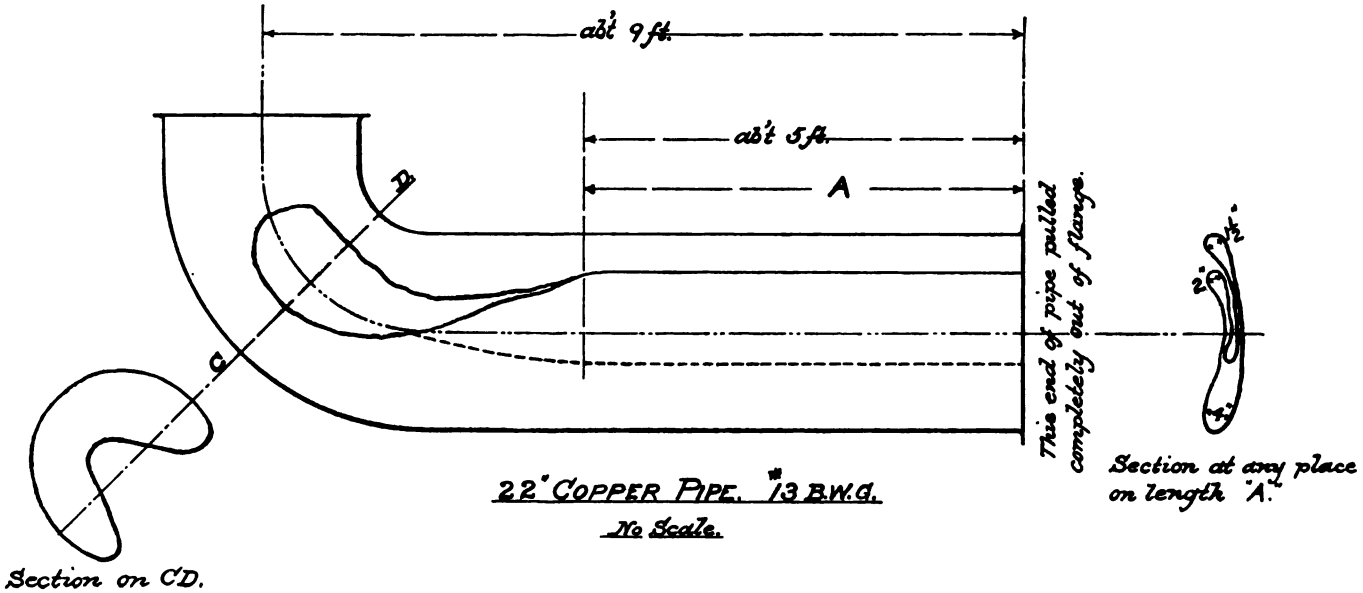

FIG. 4.

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From the steam-pipe defect a most natural step is to the illustration of bad design in piping subject to exterior pressure. A most unusual accident recently occurred on a steam yacht whereby a 22-inch copper exhaust pipe, 13 B.W.G., collapsed under an ordinary vacuum of 24 inches. This is shown in Fig. 4, and was most complete in character, the section on length A, proving the pipe to be almost as perfectly flattened as it could have been under a hammer. The straight end of the pipe pulled completely out of the flange into which it was secured, the method of securing the flange having been by turning it over in a counter-bore. While accidents of this character are not considered among the elements of great danger, the occurrence points to the necessity of more carefully considering atmospheric pressure when partial vacuums are possible, either by accident or design, within the structure.

The engineer can seldom realize until too late the closeness to which the machinery of which he has charge approaches the danger limit in many of its conditions. This is most undoubtedly true in steam pipes, where the intense forces due to expansion by the heat of the steam bring abnormal strains upon flange joints, angles and castings, which, however, are rarely indicated by any show of distress before actual casualty occurs. The most serious consideration to be borne in mind for all steam piping is the proper arrangement of slip joints for the avoidance of such excessive stresses. The ideal arrangement for a steam pipe is to have risers at the boiler and straight leads to the engines. If it is necessary to have a drop at the engines by angles to reach the throttle castings, these angles should be anchored by heavy chain bracing to the protective deck overhead to relieve the end thrust on these parts, the same general idea being adopted for the riser at the boiler end, reversing the lead of "anchor" chains. The intermediate pipe should be supplied with proper slip joints which will then act the same as the piston in a cylinder, and no strain is brought on the intermediate flanges of the piping, except such as is due to radial pressure and against which it is easily possible to make tight joints. Even these slip joints, however, may prove to be a source of danger in a certain class of

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boats (torpedo boats, for instance) whereby an accident can occur should the boat "take the bottom" and spring to such an extent as to draw the slip joints completely out. This actually occurred on one of the foreign-built torpedo boats, and in order to provide against this possibility Mr. Yarrow is now providing a trunnion joint (shown in Fig. 5), to which attention is invited as a particularly interesting and efficient feature.

Sources of danger exist often in hidden defects, especially in castings, and while the advent or advance of the mild-steel casting has decreased in a large per cent. the actual dangers due to shrinkage-cavities or blow-holes, owing to the fact that cracks do not as readily start from these as they would from the same in other metals, it is still well to understand where such defects are likely to be found.

The inferior fluidity of mild steel as poured in castings compared to that of cast iron includes a more rapid cooling and a greater difficulty in avoiding shrinkage cavities. This is well illustrated by a casting of the form shown by a section in Fig. 6. This section is from a short steam-pipe connection about 20 inches internal diameter and 3 feet long. The twelve ribs shown extended from end to end and into the flanges at both ends. The defects shown by the photograph exist opposite each fluting or rib where the metal is thickest. As the mold was made for the casting to be poured on end, the metal began to cool and solidify at the two surfaces (core and outside) very quickly after pouring, and, owing to the narrow section compared with the length of the casting, the fluid metal was unable to be fed properly from the heads during the whole process of cooling, the upper sections, solidifying beyond the flowing state before the mass was entirely solidified in the center, and when finally cooled the larger bodies opposite these ribs necessarily drew from the more liquid center, as shown, creating long shrinkage cavities in line with the ribs and nearly midway between the inner and outer surfaces.

All authorities agree that this is a difficult form to cast perfectly. The defect having been noted, the sink head would be made higher than usual, say for this casting 2 feet high, of

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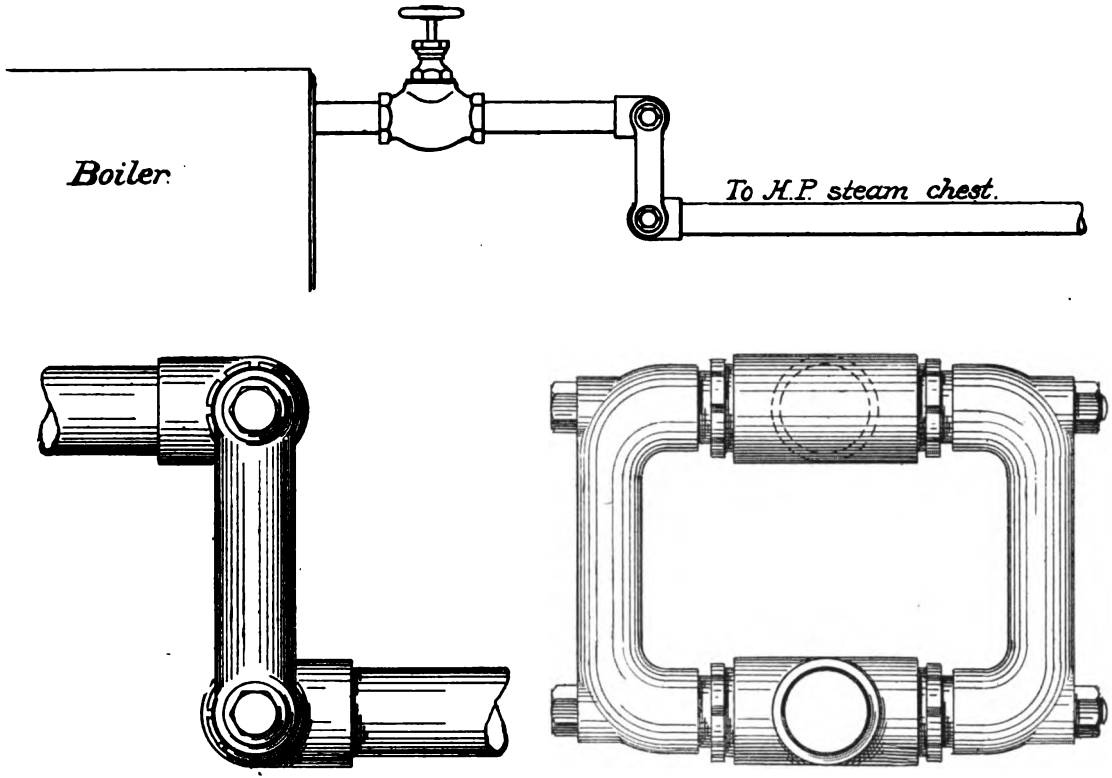

Fig. 5.

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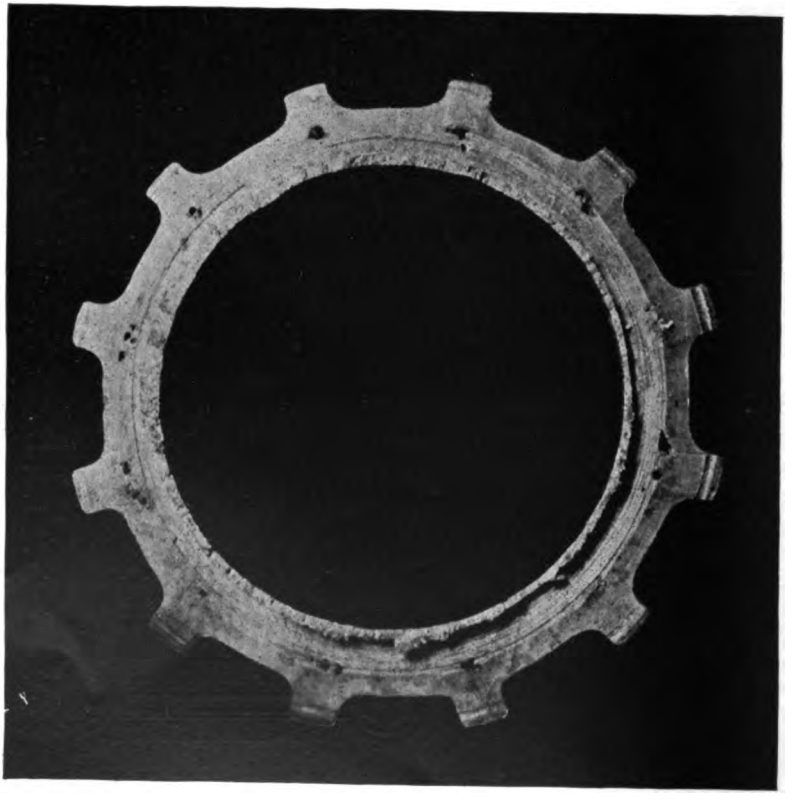

FIG. 6.

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the full diameter of the upper flange and carrying the center core to the top of the head. Where great importance was attached to absolutely perfect casting, as in this case, it would be still better to increase the diameter of the center core very greatly and bore out from the center to the desired size, thus giving a greater thickness of feeding metal and throwing the possibilities of defects much further toward the center of the casting, where machining could clear them out.

The importance of properly forming sink heads for steel castings is still not understood by all foundrymen. Very frequently the idea prevails that a large, low sink head is as good as a high one, and many castings are made with short sink heads of large diameter having the neck or connection to the mold, greatly reduced, thus losing the best effect of a proper head. The "hydraulic" pressure, as it may be termed, of course, being indicated by the height of the head and not by the diameter, the question of height to bring proper pressure and a forced feed is a serious one; and while it may facilitate the separation of the head from the casting to narrow the neck, it is in many cases a most faulty thing to do, as the imperative necessity is to get a full and free supply of molten metal to feed as the casting proper shrinks in cooling. This feeding must not be choked and must be delivered as much as possible in the central or middle line of the casting. The large, heavy, full-sized sink head noted for the casting considered here, being the full diameter of the upper flange and extending all around the casting, if added to a decrease in the central core, as suggested, could scarcely fail to make such a casting perfect.

While on the subject of graphically representing details in machinery, the writer desires to allude to the advantage of curves and sketches over tabulated lists for many of the data necessary to use in engineering. This was brought to mind by considering the table of standard rivets used by the Bureau, and for which many demands have been made recently by outside parties. Diagrams of rivets of standard dimensions as furnished by the Bureau are given here, not only to illustrate this point but to serve any of the Society who may have occa-

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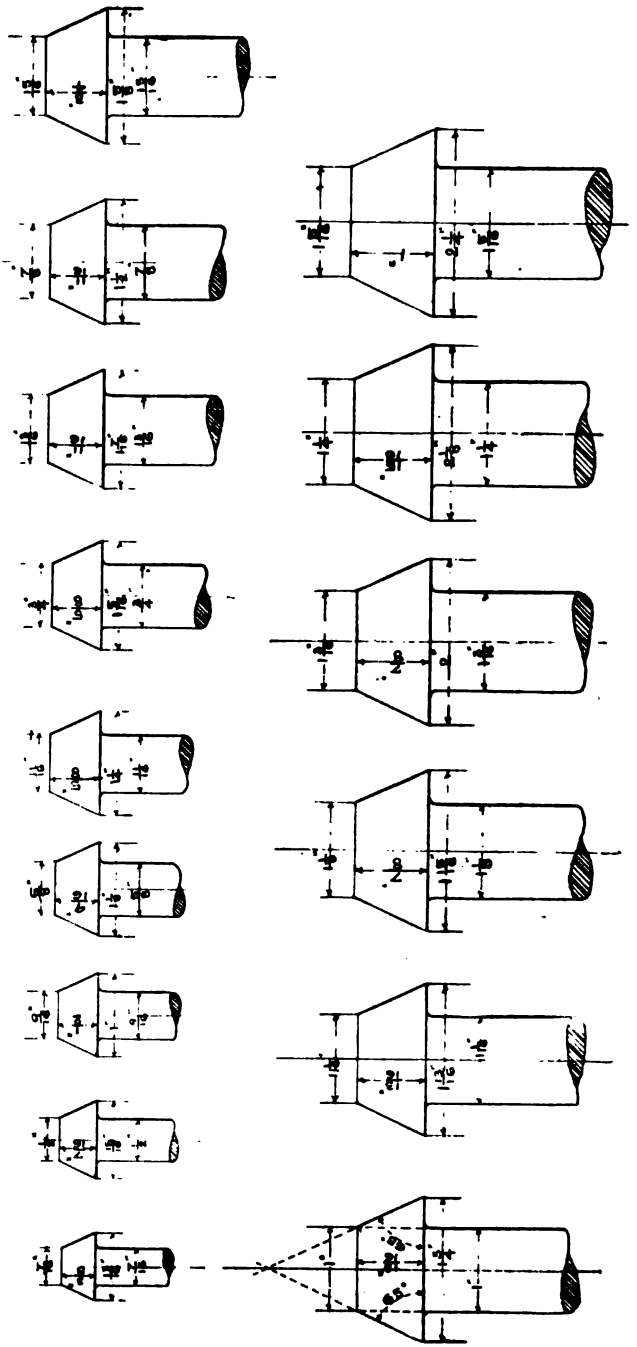

STANDARD SIZES BOILER RIVETS, U. S. NAVY.

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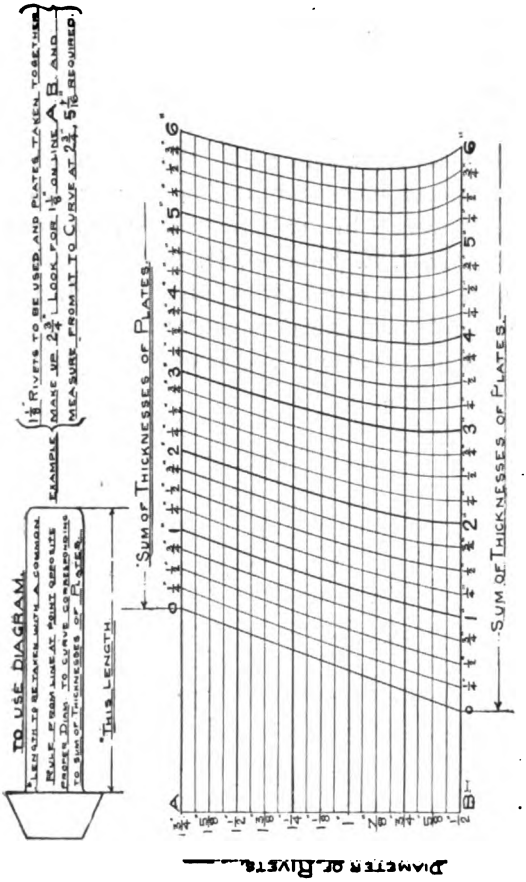
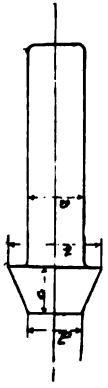


DIAGRAM FOR LENGTHS OF RIVETS.

(CONSTRUCTED FOR HOLES DRILLED 1/16" LARGER THAN DIA OF RIVETS MACHINE RIVETTING BOTH HEADS ALIKE)

STANDARD-SIZE BOILER RIVETS, U. S. NAVY.



a	2	c	2	Wt of 10 Heads
7/16"	11/16"	3/8"	7/16"	.381 lbs
1/2"	15/16"	7/16"	1/2"	.531 -
9/16"	1"	1/2"	9/16"	.713 -
5/8"	1 1/8"	9/16"	5/8"	1.007 -
11/16"	1 1/4"	5/8"	11/16"	1.373 -
3/4"	1 3/8"	5/8"	3/4"	1.551 -
13/16"	1 7/16"	11/16"	13/16"	2.032 -
7/8"	1 1/2"	11/16"	7/8"	2.258 -
15/16"	1 5/8"	3/4"	15/16"	2.871 -
1"	1 3/4"	13/16"	1"	3.584 -
1 1/16"	1 13/16"	13/16"	1 1/16"	3.91 -
1 1/8"	1 15/16"	7/8"	1 1/8"	4.761 -
1 3/16"	2"	7/8"	1 3/16"	5.17 -
1 1/4"	2 1/8"	15/16"	1 1/4"	6.215 -
1 5/16"	2 1/4"	1"	1 5/16"	7.391 -

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sion to refer to them. The diagrams are clear and far better in this form than they would be in a simple tabular one with columns for the different dimensions. Useful curves can be worked out to fit many occasions for which at present they are not used, and communications to the technical press during the last few years have indicated a greater attention to this matter by engineers. In the issue of the "American Machinist" of July 27th, Mr. J. E. Johnson, Jr., presents curves indicating the friction of compressed air in pipes, which are well worth the notice of all mechanical engineers of to-day, especially in view of the rapid advance of pneumatic tools and machinery in the industrial world.

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LARGE ATLANTIC CARGO STEAMERS.*

[Reprinted from the "Engineers' Gazette."]

Since 1891, and more especially since 1894, there has been a great increase in the size of cargo steamers employed in the Atlantic carrying trades. This has been largely due to the foresight and enterprise, first, of Messrs. Harland and Wolff and the owners of the White Star Line, of Liverpool, and more recently, of Mr. R. S. Briggs and Mr. R. M. Hudson, Sunderland, Sir Christopher Furness, and Messrs. Elder, Dempster and Co. There is practically no limit to the size of cargoes that can be obtained in America.

It is remarkable that until 1895 there were no British cargo steamers of more than 6,500 tons gross register, except the *Bovic*, 6,583 tons gross register, and *Cevic*, 8,301 tons gross register, of the White Star Line, built by Harland and Wolff in 1892 and 1893; the *Samoa*, 6,839 tons gross register, and *Maroa*, 6,802 tons gross register, owned by Messrs. Crow, Rudolph and Company, Liverpool, and built by Messrs. W. Doxford and Sons in 1892 and 1894, and always excepting the *Great Eastern*.

Of merchant steamers (both for cargo and passengers), 6,000 tons gross register and over, according to a return of Lloyds' registry, there were building in March, 1895, ten vessels, and in March, 1899, fifty-four. Among the largest cargo, or partly cargo, steamers now building are the *Saxonia* and *Invernia*, of about 13,200 tons gross register, for the Cunard Company, by the Clydebank Shipbuilding Company, Limited, and C. S. Swan and Hunter, Limited, respectively. Of merchant steamers, 10,000 tons gross register and over (cargo and passenger), there are now building in British yards eighteen vessels, including the *Oceanic*,

* A paper by G. B. Hunter, Esq., Member, read at the summer meeting of the Fortieth Session of the Institution of Naval Architects, July, 1899.

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about 17,000 tons; in German shipyards nine, and in French shipyards two vessels.

To illustrate the rapidity with which cargo steamers have been increased in size, and also the increasing adoption of twin screws, the following table from a paper read by Mr. E. W. deRussett, M. Inst. C. E., before the institution of Civil Engineers, with a slight addition, is given (all the more recent steamers were built for the Atlantic trade):

PARTICULARS OF SOME OF THE LARGEST CARGO STEAMERS BUILT EACH YEAR BY C. S. SWAN AND HUNTER, LIMITED, WALLSEND.

Year.	Name.	Dimensions.			Tonnage. Gross.	Water ballast.	Screw.
		Length. B. P.	Breadth.	Depth.			
		feet.	*ft. ins.*	*ft. ins.*		*tons.*	
1891	*Chancellor*	400	47-6	31- 6	4,753	831	Single.
1892	*Tokomaru*	425	53-0	34- 0	6,237	1,310	"
1894	*Aotea*	430	49-0	32-10	5,652	1,073	"
1895	*Westmeath*	450	56-0	34- 6	6,850	1,555	"
1896	*Milwaukee*	470	56-0	34-10	7,317	2,555	"
1897	*Monarch*	470	56-0	34-10	7,295	2,592	"
1898	*Mount Royal*	470	56-0	34-10	7,044	3,590	"
1898	*Ultonia*	500	57-4	37- 0	8,056	2,659	Twin.
1899	*Saint Andrew*	470	56-0	34-10	6,900	3,234	"
1899	*Invernia* (building)	580	64-6	41- 6	13,200 about.	4,550	"

Instead of singling out an existing steamer for description, some leading features of a typical American freight steamer of the present or early future, for carrying large cargoes across the Atlantic economically and safely, on a moderate draught was discussed. With docks, harbors and markets as they are and will be, such a vessel might be designed to carry not less than 12,000 tons deadweight, with cubic capacity for 20,000 tons of cargo at 40 feet per ton, and 1,000 tons of fuel. This would require dimensions approximately as follows: Length between perpendiculars, 500 feet; breadth, 60 feet; depth, molded, 36 feet to main deck; 44 feet to shelter deck. The draught of water, loaded, would be about 27 feet 6 inches.

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The development of the Atlantic cargo steamship will be on ship-shape lines, and not in the way of fantastic patent ships. There should not be more than three complete decks, including a shelter deck, with a partial fourth deck in forehold only. The shelter deck is practically necessary for the American trade. The space covered by the shelter deck must necessarily be exempt from measurement for tonnage dues, except when used for freight or cattle. It is reasonable and necessary that it should be so treated, because it is not required for heavy cargoes, and adds greatly to the surplus buoyancy and freeboard, and to the safety of the ship and crew, while the expense of paying tonnage dues on this space when not carrying freight in it would be practically prohibitive. With a complete shade deck there is no need for the further addition of a long bridge house, either for more space or for safety, and such further erections are undesirable. Nothing more is advantageous above the shelter deck, in a cargo steamer, than houses for the accommodation of the officers and for sheltering the steering gear, with steering house and chart house 8 feet above the deck and pilot bridge 15 feet above it. With these the height from the keel to the pilot bridge will be about 60 feet. As an instance of a greater height, plans have been submitted to his firm for building a steamer over 90 feet from the keel to the top of the steering house.

The specifications should not be allowed to include any items that will not earn 20 per cent. per annum on their cost, to cover insurance, depreciation, interest and profit. The steel decks need not be sheathed with wood, neither should wood sheathing be fitted on the double bottom. He might pass over the question of cargo-discharging appliances beyond saying there is no need for a donkey boiler, and there should be not less than twelve to fifteen steam winches of the best description. It is a question for consideration whether there should be any masts, sails, etc., or not.

As regards strength, his experience has been that with good work Lloyd's scantlings for large steamers, with some little additions, have proved sufficient for Atlantic weather. The largest ships they had built had proved perfectly strong enough

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after three or four years' work. Further experience is required to prove whether the larger steamships built on the present rules will stand ten years' heavy Atlantic work equally well. It is probable that they will. Those built by his firm are stronger in the shelter deck than Lloyds' rules require, but in other respects some of them are built simply to the rule scantlings. Of course it is necessary to pay special attention to the strengthening of deck and side openings, and to any places such as the ends of bridge deck house and the corners of hatchways where there is a sudden termination of a rigid structure or concentration of stresses. The number of rivets, spacing and size, also require special attention. The attachment provided by the latest rules for the frame feet to the margin plates of the double bottom is insufficient and should be greatly increased. Some other questions of local strength might be discussed, but structurally considered the materials and scantlings at present in use appeared to be sufficient.

Very few Atlantic cargo steamers have sufficient water ballast. From some of the Continental ports considerable quantities of outward cargo can usually still be shipped. From British ports, our somewhat one-sided free trade, together with the McKinley tariff, has so diminished exports to the United States that except to a certain extent by some special lines there is no outward cargo, or scarcely any, to be carried. It is necessary, therefore, to make the outward passage in ballast—that is to say, water ballast. The 500-feet, 12,000-tons deadweight steamer should have not less than 4,000 or 4,500 tons of water ballast, of which 1,700 tons can be carried in the double-bottom tanks, 2,000 tons in two "deep tanks," one aft and one forward, at about the quarter length, midway between the engine and boiler space and the stem and stern, and 800 tons in "'tween-deck" tanks between the main or upper and first lower decks. The latter are to be preferred for part, if not the whole, of the additional water ballast above that carried in the double-bottom tanks, not only in order to raise the center of gravity of the ballast, and so ease the motion of the vessel when rolling, but also because the 'tween-deck tanks, if properly designed, reduce broken stowage as com-

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pared with the "deep tanks," and are more convenient for loading and discharging than the deep tanks. They should be fitted between transverse bulkheads the full breadth of the 'tween decks. The position of the deep tanks should not be immediately before or abaft the machinery space. If placed immediately before the boiler room, a deep tank will sometimes interfere with convenient bunkering arrangements, and in any case with the weight of the engines and boilers and of the bunker coals for both the outward and homeward passage, necessarily concentrated in the middle of the ship, 2,000 tons of additional weight as water ballast cannot be placed in the middle without causing some alteration of form, and also causing undesirable strains on the shelter deck, and possibly on the engines and shafting. On the other hand, large peak tanks in the extreme ends of the ship are undesirable as promoting pitching, vibrations and uneasy motions. A large addition might be made to the water ballast carried in the double bottom by carrying the inner bottom straight through to the shell plating at the upper part of the bilges, and he was not aware of any reason why shaft tunnels should not be used for water ballast, as had been proposed.

The questions of propelling machinery and speed are not at the present moment very difficult, with an exception that may be referred to further on. Large steamers are more easy and economical to drive than small ones. When they run in a regular line in turn with smaller steamers it is desirable for them to be fast enough to make up on the voyage for the longer time they take in port to load and discharge than the smaller steamers. In the Atlantic larger power is required than for Eastern trades. It is understood that one at least of the great lines trading to the East is carrying cargo at only 9 knots. With head winds, steamers of similar power to that in the Atlantic would be reduced sometimes to about 6 knots. The A steamer, 11,700 tons deadweight, and B steamer, 11,500 tons deadweight, steam 11 knots average loaded, consuming 45 tons per day of north-country coals; the C steamer, 10,700 tons deadweight, 12 knots, consuming 52 tons per day (those steamers have forced draft, but not Serve tubes). The three-cylinder triple-

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expansion engines, with single-ended boilers working at 180 to 200 pounds pressure, and Howden's system of forced or Brown's system of induced draft are economical and durable, and as satisfactory, on the whole, as any other design that has been tried. This statement must be made subject to further experience of the effect of forced or induced draft on the durability of the boilers. It is largely a question of care and intelligence in working the boilers, but so far, with careful and skillful handling, there is no reason to believe that forced-draft boilers need be short lived.

The point of difficulty referred to is the question of shafting, and particularly of the propeller shafts. It is recorded in "Lloyds' List" that 173 steamships were disabled in 1898, mostly in the Atlantic, through fracture of shafting. It is stated that 53 similar accidents occurred in April, May and June this year. This can only be regarded as highly unsatisfactory. The causes usually assigned for these accidents are—the practice of steaming outwards from Europe to American ports in ballast—and generally with very insufficient ballast—the lightness of steel ships, and the reduction of their draught in ballast trim due to their floors and their lower lines forward and aft having been made so much fuller than formerly. He did not consider these causes entirely sufficient to account for the remarkable increase in the number of shafting casualties that has occurred during the last two years. They undoubtedly have much to do with the trouble, but some of them have been in operation for many years. It may be taken as established that the diameters of shafting, and particularly of propeller shafts, as required by the rules of the Registry Associations and the Board of Trade have been, and are still, insufficient. The Committee of Lloyds' Register have already increased their requirements for propeller shafts about 16 per cent., and it is believed that they have under consideration the necessity of a further increase. Greater attention is being paid to the protection of propeller shafts from corrosion and from sudden diminution of strength at the outer edges of the brass liners. These improvements will tend to diminish shafting casualties, but they will probably not be found sufficient

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to prevent them. It may be necessary to go back to the practice of having an outer bearing for the tail end of the shafts, but, for reasons which we need not enter into, he did not recommend it. He should in large single-screw vessels for Atlantic service recommend increasing the strength of the propeller shafts 100 per cent. above the present rules.

There is reason to believe that during the last three or four years not only has the practice of running steamships across the Atlantic in ballast increased, but the captains and engineers, having grown bolder and more accustomed to it, have been less careful to slow their machinery down to half speed in bad weather when the vessel is pitching and racing badly. With the old compound engines governors were used, and were at least of some use, and in very bad weather the engines had to be slowed or the machinery would have been shaken to pieces. With three-crank triple engines, governors are less effective and are now seldom used, and the main engines are not so severely tried by running through heavy seas as with two cranks. But the propellers and propeller shafts bear practically the same strains with triple engines as with compound. The shafting is smaller in diameter, as compared with the power of the machinery and the size of the ships, than under the old rules for compound engines. The bending strains on the tail-end shafts when the propellers are only partly immersed and the blade strikes the sea are as great, if not greater, in new steamers than they used to be in the old compound steamers.

Considering the enormous and incalculable strains brought on the propeller shafts with the vessel pitching and the engines "racing," there is no reason for surprise that propeller blades and shafting are frequently broken at sea. Unless it be made impossible to run the engines more than half revolutions when in "racing" weather, it may be doubted whether an increase of even 100 per cent. above the present rules would be sufficient to prevent fractures.

For large steamers carrying 10,000 or 12,000 tons of valuable cargo, the ship and cargo being valued at perhaps £300,000, duplicate engines and screws should be provided. In addition

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to the immense advantage of having an additional propeller in the event of one breaking down, the advantage of being able to use smaller screws when running in ballast is very considerable, and in a bad-weather passage will often shorten the voyage. It may be taken that twin engines increase the first cost, and usually increase the space occupied, and in fine weather are less efficient by about 5 per cent. Yet these disadvantages, together with, in most cases, a slight increase in the cost of working, are more than outweighed by the increased safety from breakdown and disablement at sea. In ships of about 500 feet long or more it may be said that twin engines are also necessary for handling the steamers in confined spaces.

It would be interesting to know the experience of other builders, but our own experience has been that the cost of building with the ordinary appliances is considerably greater per ton in very large ships than smaller ships. The cost per ton diminishes as the ship increases in size up to 5,500 or 6,000 tons deadweight, but gradually increases from 6,000 tons deadweight upwards. This increase is partly due to the larger ships being usually built on an improved and less simple specification, but is also largely due to the greater expense of handling the increased weight of frames, beams and other parts of the vessel, and the increased height to which the weights have to be lifted while building. The expenses of shoring and keeping very heavy ships in shape are also considerably greater, even than in proportion to the increased size of the ships.

The increased cost of handling the materials for big ships finally determined my firm to provide steam or electrical power, not only for hoisting the materials, but for transporting them and placing them in position. In considering the structural arrangements necessary for supporting overhead cranes, the advantages to be gained by protecting the workmen in our uncertain climate from the weather appeared so great that we determined to provide not only lifting appliances, but a complete shelter over the shipbuilding berths for the larger class of steamers we were building. They now, therefore, have covered-in sheds 500 feet long, with glass roofs and closed-in sides from about 14

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feet above the ground upwards, over two of the building slips. In each of these, two electric traveling cranes are provided on rails running the full length, and with gibs revolving below the cranes, so that any part of the ships building can be reached. One of the shed roofs is also used to support an outside cantilever crane commanding a space of 500 feet in length by 60 feet in breadth, on which a third steamer can be built.

It has been found that the work can be carried on much more quickly and economically under those sheds than under the old conditions. It has also been found, contrary to the prophecies that were uttered, that the ships under the sheds are more comfortable to work at than the ships built outside. The temperature under the sheds is higher in winter and lower in summer than outside, and though they are open at the ends and at the bottom there has been no complaint of drafts. It has also been found that there is, together with a saving in the cost of staging and increased safety, a saving in the cost of shoring and fairing the vessels, as the columns supporting the roofs are freely used as abutments for the shores, which are consequently much lighter and more handy to use than if required to reach from the ground.

The one disadvantage (which was foreseen) is that although the roof and most of the sides are of glass there is a slight diminution of light, which has to be met with by increased use of electric lighting.

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NOTES.

THE NEW GOVERNMENT TESTING TANKS FOR SHIP MODELS AT THE WASHINGTON NAVY YARD.

Many of our technical periodicals have recently published all the available data of these tanks, and have presented very interesting photographic illustrations of the several important features. We are forced to forego reproducing the illustrations, but the following description, reprinted from a paper by Naval Constructor D. W. Taylor, U. S. Navy, will be sufficient to impress a very clear idea of the structure and apparatus used:

The basin is located in the southeast corner of the Washington Navy Yard, and is enclosed by a suitable brick building 500 feet long and about 50 feet wide inside, the only openings being the doors and the windows in the monitor. The water surface in the basin is slightly shorter than the building, being about 470 feet long. The deep portion is about 370 feet long, the south end, from which runs begin, being narrow and shallow. The water surface is 43 feet wide, and the depth from the top of coping to the bottom of the basin is $14\frac{2}{3}$ feet. The basin is considerably larger than any other in existence. The nature of the ground was such as to render the construction of a thoroughly tight and stable basin somewhat difficult, but owing to the small space available at the Washington yard, it was necessary to locate it upon its present site. The bottom of the basin proper is made up of a layer of broken stone about 12 inches thick, upon which is a thin layer of concrete (about 3 inches), then a half inch of Neuchatel asphalt, then about 9 inches of concrete in sections 16 feet long, the keys between the various sections being filled with Bermudez asphalt, and the whole inside surface covered with the asphalt. The heavy side walls are 6 feet thick at the bottom, 6 feet deep, and about $4\frac{1}{2}$ feet thick on top, not counting the molded-stone coping. They are in 40-foot lengths,

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with a square key hole between adjacent lengths filled with Bermudez asphalt. The side walls rest upon a double row of piles, and in addition there is a sheet piling completely around the deep part of the tank. The shallow part of the tank at the southern extension is also carried on piling, as it actually overhangs the water.

The law authorizing the construction of the model basin also authorized experiments to be made for private shipbuilders, provided they defrayed the actual cost of the same, it being understood, of course, that such experiments should not interfere with naval work. This being the case, it was necessary to lay out the plant with a view to the rapid and economical turning out of routine experiments, and to this end the endeavor has been throughout to use machinery for as many of the operations as possible. The foreign tanks invariably use paraffine for the construction of models, and generally make them from 10 to 14 feet long. The climate of Washington, however, is so warm in the summer that it was found impossible to obtain paraffine that would retain its rigidity satisfactorily, and, moreover, it was the desire of the Bureau of Construction and Repair to make the models as large as possible, thus eliminating one source of inaccuracy in applying the model experiments to full-sized ships. For these reasons wood was adopted as a material for the models, and after some difficulty a satisfactory varnish was found which rendered the surface of the wood to all intents and purposes absolutely water-tight. The standard length of model used is 20 feet. A model 20 feet long may not seem much larger than 12 feet long, but when it is remembered that the displacements of these two are respectively as 8,000 and 1,728, it will be seen that the 20-foot model is nearly five times the size of the 12-foot model.

The method of building the model is as follows: The "lines" of the vessel's hull as developed by its designers invariably include a body plan giving sections at moderately close intervals. From this body plan new sections are drawn to the proper size for a 20-foot model, by means of the eidograph or large pantograph. These sections are cut out of paper and then transferred

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to wooden boards, which are sawed to shape. These boards are then erected in their proper relative position upon the erecting table, each board section being clamped in a vertical plane. They are then covered with battens about one-half inch thick, and tapering from amidships towards the end, making a "former" model, the surface of which is planed smooth. In cutting out the sections allowance is made for the thickness of the battens, which have to be nailed upon them. Meanwhile a rough block of such shape and dimensions that the finished model can be cut from it, has been prepared, by gluing together under pressure in a large hydraulic press, pieces of plank roughly cut to an appropriate shape. This block is placed upon the upper table of the model-cutting machine, the "former" model being placed upon the lower table. The model-cutting machine works upon the principle of the Blanchard lathe, a roller traversing the surface of the "former" model and saws or cutters working upon the surface of the model proper. The bulk of the material is removed from the block by means of the saws, which are shifted along a short distance at a time. Rotary cutters are then applied which finish the surface of the model very close to the desired shape. The model is then removed from the cutting machine and finished by hand; a very small amount of hand work, however, being found necessary. It is then ready for varnishing and the attachment of any appendages, such as bilge keels, struts, etc. It is finally taken to the measuring machine, and careful measurements are made of its exact form and shape, which not only enable the staff to determine whether the model represents the lines desired, but gives an exact record of the actual shape.

The model is now ready for the towing experiments. The carriage used in this work runs upon eight wheels and spans the full width of the basin. The platform in the center carrying the recording apparatus can be raised or lowered at will. Electricity is used to drive the carriage, and it may be mentioned incidentally that it is used for all mechanical work in connection with the model tank. The speed of the carriage is varied not only by making various combinations of the four motors—one to each pair of driving wheels—but by controlling the output of the

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generator in the power station, which is, perhaps, 100 yards from the tank. This control is on the Ward-Leonard system, and is very similar to that used to control the motion of heavy turrets on board ship. By means of a resistance box on the carriage the current through the field-coil windings of the generator is increased or decreased at will. The revolutions of the generator being kept constant by a delicate governor, the amount of current generated varies with the amount of current through the field coils of the magnet. The whole of the current generated is passed through the motors, and in practice it is found that a very exact regulation of speed is obtained by this combination.

The carriage itself, with its fittings, weighs in the neighborhood of 25 tons, so that it alone forms a kind of fly-wheel, and is not subject to sudden variations of speed. The speed of the carriage can be varied from $\frac{1}{10}$ knot an hour, or 10 feet per minute, to 20 knots an hour, or 2,000 feet per minute. The principal difficulty in connection with the use of high speeds, which, while not necessary for the bulk of the experiments will be of great value in certain special experiments, is to stop the carriage when it is once under way. The electrical control acts as a brake, because when the current is shut off the motors become generators; but this could not be relied upon for high speeds, since the sudden rush of current due to possible unskilful manipulation might throw the circuit breakers, thus opening the circuit and cutting off the current entirely. For these reasons there is at the north, or terminal end of the basin, a double system of brakes to catch and stop the carriage. The first is a friction brake consisting of two strips of iron on either side pressed together by hydraulic cylinders. These are forced apart by a slipper on the carriage about 10 feet long, which, as well as the brake strips, is kept thoroughly oiled, so that the coefficient of friction for stopping, though low, is fairly definite and sudden jerks are avoided. The pressure in the hydraulic cylinders is controlled by an accumulator and a pump driven by electricity.

Great care has been taken in connection with this part of the installation that it may be always in working order, and any trouble or breakdown, except that of the pump itself, which runs

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all the time, will simply result in setting the pressure at a maximum. This maximum is 600 pounds, but it has been found by actual experiment that with 500 pounds pressure the carriage is brought safely to rest when it enters the brakes at a speed of 20 knots. It is not expected in practice to repeat this often, since even for the high-speed runs the electrical brake will be used to reduce the speed of the carriage before the friction brake is used. In addition to the friction brake, there is what is called the emergency brake, so that in case the friction brake fails for any reason, the carriage would still be caught. This brake consists simply of a piston about 16 inches in diameter, working in a cylinder which is submerged in the water of the tank and connected by wire cables to a hook which takes hold of the carriage. The head of the cylinder has a round hole, and the piston rod is tapered so that as the rod is drawn out by the motion of the carriage the hole is gradually closed, the whole being almost exactly upon the principle of the hydraulic gun recoil brake. An escape is provided for the water around the piston when it starts from rest, to avoid sudden acceleration of the whole mass of water in the cylinder.

The dynamometric apparatus is designed to avoid entirely the use of multiplying levers or other devices involving the possibility of friction, and here again electricity is enlisted. The recording drum is, as usual, fitted with apparatus for recording the time and distance. The resistance is measured directly by a spring arrangement, which is placed underneath the carriage. The forward end of the spring is attached to a bracket which is screwed forward or back by an electric motor, and a rigid arm runs up from the bracket, with a pencil recording its position on the drum. The record then is of the position of the forward bracket. The after end of the spring takes hold of a small crosshead to the other end of which again is attached a towing rod, which takes hold of the model. This crosshead has a very slight play between stops in the after fixed bracket, and when it touches either stop closes an electrical contact which again throws an electric clutch, by means of which the motor, running all the time, screws forward or back the forward bracket, thus

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increasing or decreasing the tension of the spring until the contact is opened again.

There are many refinements which cannot be indicated in this brief description; for instance, the operator can throw either clutch at will or set them to work automatically. In practice, when about to make a run, the operator works the bracket forward to the immediate vicinity of the position which he knows it will assume during the run, the approximate speed of which he knows. The carriage is then started, and after a uniform speed has been obtained, which, for speeds up to 12 knots, is done within 50 feet, he throws in by a single motion of one handle the automatic appliances which start the drum and record time, distance and resistance. In this way the resistance pen has to move but a small distance to reach the position of equilibrium and almost immediately becomes steady. With this device friction is eliminated. The accuracy obtainable depends upon the closeness with which the automatic stops at the after end of the spring can be set. In practice it is found that those can be set to give a play of about $\frac{1}{50}$th of an inch, and, as the springs will extend 10 inches, the results obtained are practically exact as indicating the pull of the spring.

It now remains to describe the method by which the amount of this pull can be determined in any instance. There is fitted at the starting end of the basin a kind of weighing machine with one vertical and one horizontal arm. This is delicately balanced, and when the model has been connected up and is ready for towing, a certain spring being in use, the vertical arm, or rather a knife edge which bears upon the vertical arm, is connected to the model. A known weight is then put into the scale pan attached to the horizontal arm. The automatic attachment in connection with the dynamometer spring is thrown into gear and the weighing machine is screwed forward or backward until it is in perfect balance, and the record pen recording the position of the spring is at rest. It is evident that the pull of the spring is exactly equal to the weight in the scale pan. There are a number of pens which can be shifted parallel to the recording pen and set in a definite position to record upon the drum. One

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of these pens is set to correspond to the position of the resistance pen, then another weight is put into the scale pan, a second pen set to record the resistance, and so on. It is evident then that when the run is made these fixed pens mark off upon the paper a scale for resistance, avoiding all complications of corrections for temperature of spring or anything else. A complete double outfit of springs is already provided for measuring resistance from 1 up to 500 pounds, and for special work additional special springs will be obtained.

In connection with the question of temperature, it is impossible to avoid a certain variation of the temperature of the water, but as ample heating facilities are provided, it is not expected that the variation of temperature during the year will be sufficient to necessitate correction in the results of experiments on this account. The basin is filled from the water system of Washington, and will hold 1,000,000 gallons. Two electrical centrifugal pumps are provided, the larger of which will empty the tank in about four hours. The smaller pump is a 4-inch pump used for draining the last water from the basin, and also for pumping the water from outside the basin to avoid the possibility of undue pressure upon it in case it is left empty for some time. This is necessary, since the basin is but a short distance from the Potomac River, and extends 8 or 9 feet below mean low-tide level. A gage indicates the level of the outside water, which is found to be, as a rule, about 6 feet below the water in the basin.

The leakage from the basin, which is very slight, and the evaporation, are made up with filtered water, an animal bone filter being installed with a capacity of from 50 to 100 gallons per minute, depending upon the turbidity of the water. In practice, a small stream of fresh filtered water is kept running into the basin all the time and the level maintained wherever desired by an adjustable overflow.

Experiments are being made as opportunity serves upon models of the naval vessels already built and tried, for the purpose of accumulating data which will be constantly needed during the life of the tank. As soon as preliminary lines of the new third-class cruisers authorized at the last session of Congress are completed,

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experiments will be made with them in the tank with a view to introducing any refinements or improvements found desirable.

SALE OF CONDEMNED WAR VESSELS.

On July 19, 1899, bids were opened at the Navy Department for several of the vessels purchased at the beginning of the war but which after the termination of hostilities were found to be unfit for service. The following list gives the details of cost and selling price:

Name.	Cost.	Appraised value.	Bid.	...
Governor Russell	$71,000	$35,000	$25,000	Withdrawn.
East Boston	57,500	30,000	38,091	Sold.
Vulcan	350,000	100,000	175,500	Sold.
Scipio	85,769	25,000	50,125	Sold.
Niagara	200,000	60,000	75,563	Sold.

The *Enquirer* was withdrawn and transferred to the War Department.

THE DAY OF AUTOMOBILES.

In speaking of this the Editor of the "Electrical World" says: If one thing stood out more prominently than another at the recent very successful electrical exhibition in Madison Square Garden, it was the deep impression caused by the electric automobiles shown there. Nor was the impression that of mere gaping wonder. It was largely a wealthy crowd that frequented the Garden, and the automobile exhibitors could have sold out their vehicles over and over again. It was also a varied crowd, for one concern alone, which sold some thirty carriages and wagons during the show, has to deliver the vehicles at about as many different points in this country and abroad. The orders and inquiries received by all the exhibitors leave barely a single part of this country untouched.

This is a striking manifestation of interest in the new departure, but the question remains to be settled: Who is to do the charging? And it is here that the alert central station

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manager should find his new opportunity. It is not likely that all the business will come his way, but a large proportion will be his if he cares to develop a day load or to operate to advantage in the idle hours of midnight. The possibilities are these: There are said to be in New York City, for example, 5,000 ply-for-hire vehicles. If each of these took 50 cents' worth of current daily, as electrics, the consumption of current would reach not far short of $1,000,000 per annum, and it may be questioned whether another kilowatt of generating capacity would have to be installed to help furnish the current. Each manager can figure on the 'proposition' for his own locality.

But this is not all. One hears a good deal to-day of the severe limitations of electricity as compared with gasolene and naphtha. Something might also be said, per contra, about the severe limitations of gasolene and naphtha. There will be plenty of room for all classes of automobiles, but for ourselves we beg to be excused from the odor and jolting of vehicles propelled by gas, steam or oil. Electricity is, we must confess, good enough for us, and we believe that the facilities for charging electric vehicles will soon be abundant, not only within the cities but for many miles outside them, along every decent road. A time is rapidly coming when every enterprizing road house and country wayside hotel will have its little charging plant ready to start up and do its work while the driver gets his glass of beer and a sandwich. The same plant will do the lighting at night, and thus through the automobile electricity will have received the stimulus in rural districts for which it has long been waiting. This plan does not anticipate greatly the probable march of events in the next few years.

LIQUID-FUEL EXPERIMENTS.

While the Bureau of Steam Engineering has in hand the work of continuing experiments with liquid fuel and proposes to secure at an early date data that will be of real value, and upon which the question of the practical adaptability of heavy oil as fuel for our torpedo boats will be finally settled, it is interesting to note the discouragement which is felt by the English over

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the failure of the experiments on the *Surly*. This, however, in no way prejudges our own results. The "Engineer" (London) of June 23, 1899, says: The oil-fuel trials in the torpedo-boat destroyer *Surly* have virtually been abandoned, it having now been demonstrated that unless special arrangements are made for consuming the smoke the adoption of oil as a fuel is impracticable. When the experiments commenced, about a year ago, great expectations were formed, as it was believed that the liquid fuel would be cleaner, cheaper and so far automatic in its feed as to save a considerable amount of labor in the stokehold. Throughout the whole of the trials, however, the *Surly* only once went to sea, and then it was found that, owing to the low evaporative qualities of the oil, the speed and power were far inferior to what would have been produced by coal. But it was hoped that by improved appliances to so obviate the escape of heat that this difficulty would be overcome, while the absorbing problem was the question of smoke abatement, and to this no solution has been found.

Had the authorities been resolved to create the maximum of smoke with the minimum of steam, they could not have succeeded better; but this was the exact opposite of what they were striving for. Nor was this one of those experiments that are foredoomed to failure, because the order was given that every mechanical contrivance was to be exhaustively tested until success was assured, but from first to last there was no diminution in the density, the dirtiness or the nauseous smell of the smoke.

Our contemporary, the "Naval and Military Record," finds comfort in the failure of liquid fuel, not merely because the adaptation of existing machinery to the new conditions would be expensive and tedious, but because it would be necessary to maintain reserves of oil at all the coaling stations, thus involving risks that are anything but desirable.

NAVAL STATION, CAVITE, P. I.

A very good idea of the facilities for repair work commanded by the Spanish forces at Cavite can be gathered from the fol-

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lowing extracts from the journal of Naval Cadet Daniel S. Mahony, written while he was on duty there shortly after the station was taken possession of by our forces. It is frequently a marvel to naval officers to see the quite excellent quality of work that is produced with rattle-trap machinery at some of the foreign stations, especially where the natives have naturally the leaning towards mechanical arts and possess the patient manual skill that is found in the orient. Mr. Mahony says:

The naval station is situated on a peninsula between Baker Bay and Canacao Bay, the town of Cavite and Fort San Phillippe being also on the peninsula.

The buildings are old, and in no way suited to a modern engineering establishment. The first one contains the machine shop and blacksmith shop, with boilers and engines to run the same. Three heavy stone walls divide it into four parts.

The boilers are old-fashioned affairs on the Lancashire plan, furnaces running their whole length. The furnaces have Galloway tubes. Steam pressure is around 20 pounds, and much more would be hard to get with such a leaky combination of pipes and valves as is on these boilers.

The machine-shop engine is a vertical, direct-acting, single, inverted affair, feed pump attached, worked by an eccentric, and slide valve worked by a second crank. It is of interest solely as a relic.

The machinery in the shops is poorly placed. All of it is of the old, heavy type, and none of it good. The centers of most of the lathes wobble. The shapers are very old fashioned. There is only one gap lathe in the shop. There is no floor; the earth is rough and uneven, and the roof leaks. On one side the roof is of tin with large skylights, the other half of the shop has a solid roof and no windows on one side, so much of the work is done by candle light.

The blacksmith shop has modern forges, none of them very large. It has a blower run by belting from the machine-shop shafting. There is a large steam hammer valuable as a curiosity, and a small one somewhat better. There are no facilities for any heavy forging. The shop has the usual tools and French anvils.

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The boiler shop is merely a big shed. It has five forges, two shearing and punching machines. There is also an immense old punching machine long past use. Power is furnished by a small horizontal engine, taking its steam from a Cornish boiler, of which there are two.

The foundry contains three brass furnaces and three cupolas, all of which need rebuilding, a small engine and a blower. There is no elevator behind the cupolas; all metal has to be carried up on the platform behind them. Their capacity is 1½ tons. A fairly heavy casting can be made directly in front of the cupolas, where is a track on which a truss is mounted on wheels. Heavy ladles can be swung from this truss. It is hard to say whether the natives do green-sand molding or dry-sand molding, as they use green sand and build fires under the molds. Cutting a pattern in two they never heard of, but with trowels and slickers they make very intricate molds.

The pattern shop is primitive. It contains a bench with one vise, a few chisels, planes, hand saws, bow saws and a lathe. The last consists of two parts: a table on which are two centers, one adjustable, and a wheel some six feet in diameter, much like a cart wheel. A piece of wood to be turned is placed on the centers, and a rope belt put around it and around the big wheel, and while two men turn the latter, a third holds the tool against the revolving wood. The natives much prefer, however, to sit upon a table, holding the piece of wood with their bare toes, and rounding it with a jack plane.

The marine ways are ordinary wooden affairs, a wooden bed sliding on rollers between wooden guides. The ways are moved by a large winch. The large ones are about 175 feet long and some 15 feet beam. The small ones are not over 100 feet long. The ways in the boat shed are an ordinary car track with a flat car on them. There is on the sea wall a large shears, good for about 25 tons, and a small crane, for perhaps 3 or 4 tons. These are the only lifting facilities in the yard. Both are worked by hand.

An old-fashioned car track runs around the yard, and there are a few flat cars, but no locomotives.

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The shipbuilding shop is the most modern thing in the yard. It has two Cornish boilers, and two large horizontal engines, modern. They have good governors and an expansion valve. A third eccentric on the shaft works a feed pump, which takes a brine mixture from a well. The machines in the shop are all rather old fashioned, like everything else in the yard; still, if one can do with old fashioned things, there shouldn't be much trouble in getting along in a modern shop.

A large amount of work for the fleet has been done in the yard. In the foundry castings have been made for furnace fronts, bridge walls, pistons, pump chambers, etc., to say nothing of smaller articles. The blacksmiths have made heavy davits. In the boiler shop a boiler has had a new furnace fitted, been retubed, new stays put in; in fact, over half rebuilt. This work is worth bragging of, considering the means at hand.

THE COST OF LIQUID AIR.

Now that liquid air is easily procurable, at least in New York City and vicinity, by anyone who wants to dabble in it, and at a cost which is not prohibitory, the enticement to speculate as to its possibilities, and to practically experiment in its use, is an unusually strong one, and not without promise of profit.

In the present state of our knowledge, and with our present resources of skill, we must, of course, abandon from the beginning all expectation of being able to realize from the liquid air anything like the power that is employed to produce it; but, having thus given up whatever hopes we may have entertained in that direction, we immediately begin to discover conditions which strongly favor its adoption for certain purposes. The bugbear of power cost is worked for more than it is worth in many engineering fields, and especially so throughout the entire range of compressed-air service. Power is really one of the cheapest instead of the dearest things with which we have to do, although it must be carefully considered in many undertakings. The story of the employment of compressed air, now so extensive, is nowhere one of high economy in the use of the original

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power, and in some of the most extensive and established applications of compressed air the losses, or, if you choose, the wastes, of power are enormous. But these very places, as, for instance, the air-brake service, and rock-drill mining, are the places where the alert readiness of the air renders it, after all, a most valuable and indispensable servant.

It will be interesting to note first what is the bottom cost of liquid air according to our present information. It is unnecessary, and it would, indeed, be foolish and unprofitable to attempt any minute accuracy in our estimate until the data upon which it may be based are close and reliable, as they certainly are not at present. We can, however, form a tolerably correct idea of what liquid air can be produced for, and at what price it will, before very long, be possible for the prospective user of liquid air to buy it.

In the "American Machinist," June 15, we have a little account of the interesting air-liquefying plant, in New York, of the General Liquid Air and Refrigerating Company. In the presence of this admirable installation Mr. Tripler's occupation as a producer of liquid air seems to be gone entirely. Here is a plant which, working at about 200 horsepower, will produce a gallon of liquid air per minute. In this simple statement is contained all that is necessary to enable us to approximately estimate (no guesswork about it) the cost of the liquid produced. It is a question of the cost of the horsepower used, and nothing beyond that, any more than there is anything else to be considered in the working of a pumping engine, or of the engines that drive a ship through the seas. There are practically no materials to be provided but the fuel, and the only labor is of the engineer and fireman class, with the necessary supervision.

The cost of power as developed by the steam engine varies widely according to the style of engine employed, and in a lesser degree it is affected by the local rates of fuel and labor and other conditions. The cost per horsepower hour has been computed and tabulated for all the various conditions, so that it is not at all necessary to compute them. In a table by the late Dr. Chas. E. Emery, which was published in the "American Machinst" April 1, 1897, the

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total cost of a horsepower hour (covering coal, labor, supplies and repairs, sinking fund, taxes and insurance, with 5 per cent. added to total, and interest at 10 per cent.) is given as ranging from $0.0254 for an ordinary non-condensing engine to $0.00919 for a compound condensing engine, and $0.00811 for triple compound. If liquid air ever becomes a staple commodity, and one of the necessities of modern life, which is not impossible, it may safely be assumed that then engines approaching the highest economies will be employed in its production. For our present purposes I am disposed to assume $0.015 as the cost per horsepower hour, which is somewhat higher than the rate given in the table referred to ($0.0143) for an automatic cut-off, non-condensing engine.

In the plant we are considering, 200 horsepower produces 1 gallon of liquid air per minute. As a gallon of liquid air weighs (nearly enough for our purpose) 8 pounds, the 200 horsepower in one hour, or 200 horsepower hours, would produce $60 \times 8 = 480$ pounds of liquid air; so that 1 pound of the liquid would cost $200 \div 480 = .416$ horsepower hour. Professor Morton, by the way, computes the cost of liquid air as produced by Mr. Tripler at 10 horsepower hours per gallon, or 1.25 horsepower hours per pound, which is almost exactly three times as great as our .416 given above. As our cost per horsepower hour is $0.015, the cost of 1 pound of liquid air will be $.015 \times .416 = .0062$, and $.0062 \times 8 = .0496$—say 5 cents per gallon. This may be taken, I think, as a fair estimate of the cost of liquid air at the works. Milk retails in New York as low as three cents per quart, or twelve cents per gallon, so that we may some day see liquid air selling as low as cheap milk, although it may still be some time before it is commonly used.

Having the liquid air thus begging to be employed, the next thing to promote its use is the facility with which it may be transported. No franchises and no favors are required from any municipal authorities. There need be in its interest neither pipe-laying nor wire-pulling. Any truckman may carry the liquid anywhere. Stores of it may be established at different points, so that anyone could replenish his supply without going far.

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Supposing vehicles to carry liquid air for propulsion, no time would be lost in recharging.

I am not here advocating the use of liquid air for vehicle propulsion, or for any other purpose, but simply trying to get an idea of the prospective cost of the liquid for anyone who may propose to use it. It is not likely that, for a considerable time at least, the air will generally be procurable "at cost," as I have here figured it; so that if anyone is thinking of using it, say for automoblie work, he must put his figures much higher than mine as here given. And then the constant loss of the liquid by evaporation, the leakage over the top of the vessel which contains it, must never be lost sight of. There is no way in sight of storing liquid air tight and safe; so that practically it must be used nearly as it is produced. It will not keep over night. The loss may be kept quite low with suitable insulation, and the larger the quantity stored, the smaller the proportionate loss; but still the pull will be unremitting, and all in one direction.—Frank Richards in "American Machinist."

NEW DRY DOCK FOR THE BOSTON NAVY YARD.

Work has already been commenced on this dock, and it is to be completed within thirty calendar months.

The borings made at the site of the new dock show that at a depth of about 25 feet below mean low water a bed of compact clay and gravel is encountered, with some thin sand strata, possibly containing water. The position of the new dock is about midway between the old stone dry dock, finished in 1833, and the larger of the two "wet basins," and parallel to the old dock. The general dimensions of the dock will be as follows.

	Ft. Ins.
Length on coping, from head to outer end of table	788–0
Length on coping, from head to outer gate sil	750–0
Length on floor, from head to outer gate sill	729–0
Length on floor, from head to inner abutment	689–0
Width on coping in body	114–0
Width on floor in body	72–0
Width on coping at abutment, least	101–8⅝
Width at entrance on mean high-water level	100–0
Depth from coping to mean high water	5–2
Depth from coping to floor, in body	39–2
Draft over sill at mean high water	30–0

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Under the terms of the contract this dock is to be built of concrete, with-rubble stone fillers, and lined with cut-stone masonry. When the excavation has sufficiently advanced so as to fully expose the character of the underlying material, the Government will decide whether piles shall or shall not be used under the dock; the present borings, however, would indicate that the soil is sufficiently compact to omit piling. A price for piling and framing, in accordance with plans made, was obtained in the bids submitted, to be separately considered. In addition to the dock, there will be a pump house, one story in height, built of granite, with steel roof trusses and copper roof. The necessary culverts and wells will be made of concrete and lined with glazed brick. There will be three main drainage pumps, of the centrifugal type, with separate electric motors, balanced and driven by vertical compound engines, and four steel boilers will be included in this plant. The steel caisson, or floating gate, with all its pumping plant and machinery, is included in the bid for the complete dock; but a separate item covers the steam generators in the central power house, the pumps, engines, dynamos, electrical capstans and winches, and all piping and connections, and all machinery, excepting the machinery in the caisson. The contractor is also required to excavate a channel from the entrance to the dock, and one foot below the table end of the dock, to a point in the harbor where a corresponding depth is reached.

The pumping plant will include three independent centrifugal pumps, with separate motors, for pumping out the dock; and one centrifugal drainage pump and motor. There will be two vertical, cross-compound, condensing, automatically-governed engines, with each engine connected with two dynamos; and also four steel boilers. The pumps admit water on both sides of the disc, and the runner shaft will be directly connected with the armature shaft. The general plan calls for an average discharge for each pump of 43,000 gallons per minute; the minimum required mean discharge duty of the three pumps is thus 135,000 gallons per minute, measured while pumping from mean low water to floor level. The efficiency of the machinery in the

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pump well must not be less than 55 per cent. The main pumps, as designed, contemplated a 6-vane runner, 79 inches diameter, a single 45-inch discharge pipe, and two 32-inch suction pipes, joined by quarter-turn bends to each side of the pump casing, and inclosed runner, so as to balance the runner and avoid end thrust. There will be three double-gate valves to each pump; one on the discharge and one on each suction pipe. The drainage pump will have a 34-inch runner, and be direct-connected to an electric motor placed on the same bedplate; the suction and discharged pipes will be 14 inches diameter.

There will be four 200-kilowatt dynamos, of the compound-wound, direct-current, constant-potential, 125-volt type, arranged for direct connection with overhung armatures. The fields are to be multipolar; and the commercial efficiency of the dynamos must not be less than 92 per cent. with full load; 90 per cent. with half, and 85 per cent. with quarter load. One 300-kilowatt motor will be directly connected to the runner shaft of each of the three main pumps, and one 50-kilowatt motor will drive the runner shaft of the drainage pump. Each engine, running two dynamos, will run, condensing, with 100 pounds initial steam pressure and 26-inch vacuum, and develop continuously 600 I.H.P. The working boiler pressure will be 125 pounds gage, and the speed of the engine is to be 150 revolutions per minute, with a variation in speed not exceeding 1 per cent. with any change of load.

The steel caisson, or floating gate, will have an extreme length of 104 feet $2\frac{7}{16}$ inches; molded breadth, 22 feet; and a depth of 36 feet 5 inches from the bottom of keel to the under side of upper deck. It will be built, as far as possible, of open-hearth steel, with welded members of wrought iron. The keel and stems must be 30 inches wide, outside of channels, and made of two 15-inch by 55-pounds channels connected to side plating by rivets spaced $4\frac{1}{2}$ inches on centers. The transverse frames are spaced 24 inches on centers, alternating 5 by $3\frac{1}{2}$ inches by 13.6 pounds, and 5 by $3\frac{1}{2}$ inches by 17.8-pounds Z-bars.

The channel for gate packing, running the entire length of the

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keel and stems along the outer edge on both sides of the caisson, is steel, 10 inches by 25 pounds, fastened by $\frac{7}{8}$-inch rivets. Inside these channels is fitted a thick rubble packing secured by an oak timber 5 inches thick. In the hull of the caisson will be 13 20-inch valves connected with 20-inch wrought-iron culverts, for flooding the dock, and there will also be two 20-inch sinking valves for use in settling the caisson into place. The centrifugal pump in this caisson will have a capacity of 3,000 gallons per minute with mean lift, and it will be driven by an inverted, vertical engine of acceptable design. The bottom of the caisson will be filled with Portland cement concrete ballast, and there will also be sufficient movable cast-iron ballast to give the caisson a floating draught of 18 feet 6 inches.

The six electric capstans, three on each side of the dock, will each be operated by a 22.5-kilowatt motor, contained in a pit 5 feet deep under the capstan. Three electric winches, of about 25 kilowatts each, will also be installed, one at the head of the dock and one on each side of the entrance. There will be a separate underground circuit leading to these capstans and winches from the power plant.

The completion of this dock will be one of the most important steps towards promoting the Boston Navy Yard to the rank held by the yards at New York and Norfolk, that of a first-class modern repair station.

THE INFLUENCE OF CASTING TEMPERATURE UPON STEEL.

In a recent paper Robert Abbott Hadfield says: This question is especially surrounded with difficulties on account of the fact that the casting temperature of steel is only known approximately, even with the latest form of pyrometers. Useful work has been carried out in France with the Noel and Mesuré optical pyrometer, but while it is claimed that much has been learned from its use, at the best it only gives approximate results. Seeing that Mr. H. H. Campbell, in his excellent paper on "The Open-Hearth Process" (American Institution of Mining Engineers, 1895), states that even a difference of 20 degrees to 30

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degrees centigrade causes considerable changes in the behavior of molten steel during casting, it will be understood how important it is that a thoroughly practical pyrometer, which would enable us to detect such differences, should be perfected. Mr. Campbell's remarks on this subject are so important that it may be well to quote them fully. He states that an addition of 100 pounds of scrap to a 7-ton bath (100 pounds ÷ 15,700 pounds) will cause the temperature to fall about 16 degrees or 20 degrees centigrade, and that this variation is perceptible to the naked eye.

An excess or deficit of (500 pounds ÷ 15,000 pounds) in the addition of scrap on the same weight and heat makes the charge either so hot that it causes trouble, or so cold that it skulls badly in the ladle. A variation of 200 pounds from the true amount, which would show by calculation a variation of about 30 degrees centigrade, is the greatest error allowable in good practice.

Incredible as it may seem, within these narrow limits lies the success of the blower and the melter. Perhaps the best practical pyrometer available, naturally varying according to individual circumstances, is practical observation by the eye, as there are no absolutely correct data as to the temperature at which steel should be cast. If steel is cast too hot the ingots or castings are liable to be piped considerably, even though the utmost care be used in pouring, and there are other difficulties, such as segregation. If cast too cold the metal produced will not work as satisfactorily as it should do during forging, and the ingots will probably be round and unsatisfactory on the exterior.

A very peculiar appearance is noted in crucible steel which is cast too hot; it is usually known as "scalded" steel. The crystalline structure is very pronounced, but by careful reheating the peculiar appearance noticed seems to disappear, though it is questionable whether the product is even then entirely satisfactory. In a recent correspondence of the writer with Messrs. Huntsman, of Sheffield, who still carry on the manufacture of crucible cast steel, founded by the well-known inventor, Benjamin Huntsman, in 1740, it was stated that to obtain the best quality, scalded steel could never be retreated except by remelting. It will be seen, therefore, that the greatest possible care

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should be taken to have the steel prepared during its course of manufacture in such a way as to obtain the happy medium of temperature, that is, neither too hot nor too cold; but until more perfect pyrometers are produced this can only be obtained with constant liability to error.

TABLE I.—*Showing Colors of Steel at Various Temperatures from 650 Degrees to 1,300 Degrees Centigrade.*

Hadfield.

Color.	*Temperature.*	*Color.*	*Temperature.*
White,*	1,240	Bright red,	923
High yellow,	1,130	Medium red,	795
Yellow,	1,081	Blood red,	667
Low Yellow,	971		

Pouillet.		*Bowker.*	
White,	1,300	White,	1,204
Orange heat,	1,100	Very bright red,	1,010
Cherry red,	800	Bright red,	926
Red heat,	525	Full red,	804
		Red heat,	650

The table of temperatures, Table I, has been found very useful by the writer in everyday work. The first part represents the author's results obtained by means of a Le Chatelier pyrometer suitably protected in the furnace; this pyrometer is an admirable one so long as it does not come in contact with molten metal. Part two represents similar comparative temperatures taken from Pouillet's tables, and part three is from a table prepared by an American expert. There is also added in Table II the melting points of various metals, also the temperatures noticed during industrial operations obtained by Mr. H. Le Chatelier and others, both with electrical and optical pyrometers; these are in some cases necessarily approximate for the reasons before given.

* Not welding heat.

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TABLE II.—*Temperatures in Degrees Centigrade of Melting Points of Various Materials.*

		Degrees.
Melting point of	Sulphur,	448
	Gold,	1,045
	Palladium,	1,500
	Platinum,	1,775
	White swedish (4 % carbon),	1,135
	Gray-foundry iron (3½ % C, 1¾ % Si, ½ % P),	1,220
	Soft steel (0.10 % C),	1,475
	Hard steel (0.30 % C),	1,455
	Hard steel (0.90 % C),	1,410
6-ton converter,	In the ladle,	1,640
	In the ingot mold,	1,580
	Reheating furnace,	1,200
	Ingot under steam hammer,	1,080
Siemens-Martin furnace (steel containing about 0.30% C):		
	End of fusion period of cast iron,	1,420
	Refining point of the steel,	1,500
	Steel in the ladle (commencement),	1,580
	Steel in the ladle (end),	1,490
	Temperature of gas from producer,	720
	At the entrance to the regenerator,	1,400
	When leaving the regenerator,	1,200
	When arriving at the chimney stack,	300
Siemens-Martin furnace,		1,600
Rotating puddling furnace,		1,230 to 1,330
Blast furnace working on gray Bessemer near tuyeres,		1,930
Commencement of the blast,		1,400
End of the blast,		1,570

STORAGE BATTERIES.

The growth of storage-battery service in this country has been slow and the development of the industry of its manufacture has been marked by a succession of failures. In spite of the adverse conditions which have surrounded the introduction of this useful

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appliance, however, the advantages to be derived from it are so great that it has come to be employed on a very large scale, both in lighting and power stations. The great importance and economic advantage of the storage battery as a supplement to dynamos of central stations and in isolated plants was recognized and taken advantage of at a much earlier day on the Continent of Europe than in America.

In 1892 one of the things which surprised the American visitor at the Electrical Exhibition in Frankfort was the great size of the storage plants installed there. The time has now come when we do not need to cross the water in order to see storage batteries of large capacity in daily commercial use, and, indeed, some of the largest installments of this kind are to be found in our American cities.

When we inquire into the reasons for the delay on the part of American engineers to take advantage of the storage battery, we find our answer in the fact that for many years it was impossible to purchase at any price batteries capable of giving satisfactory service. That time is past, and we can now obtain such batteries, but the introduction of them on a large scale is still greatly impeded by the high prices at which they are held. If we consider, for example, the relation between the cost of crude copper and the cost of copper made up into insulated wire, and compare the margin existing in that industry with the margin which exists between the price of lead and its oxides, and the price of the same materials when combined in the cells of a storage battery, we obtain a very good indication of the backward state of the industry of manufacturing these batteries as compared with the advanced state of many other industries. No better criterion, perhaps, can be had in such a matter than the relation between the cost of the manufactured article and the crude material from which it is made. Storage batteries in large sizes, where a single element, for example, weighs one hundred and fifty pounds and upwards, are quoted at about thirty-five cents a pound. The price per pound of the materials which go into such a cell are probably not more than one-sixth of the above.

Of the two processes invented, respectively, by Planté and Faure

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for the production of the plates of secondary batteries, that of Faure appeared for many years to have supplanted the earlier method of Planté altogether in commercial practice. At the present time, however, both processes are used in modified form. The modifications in the processes of Planté consists chiefly in previous chemical treatment of the lead plates for the purpose of hastening the electrolytic or forming action of the current. For this purpose numerous pickling baths have been proposed, the first of which, consisting of nitric acid, was due to Planté himself. Other liquids are frequently used, but in general the principle is simply that of starting the oxidizing process at the surface of the metal.

A great variety of modifications of the grid which forms the skeleton of all Faure plates and which holds the active material applied to this type of battery in place, have been devised, the object in every instance being the same, namely, to provide a form which shall hold the oxides most securely and thus obviate the annoyance and difficulties arising from buckling and from the shedding of the paste on the surface of the plates. Many elaborate forms of grid have been made to attain this end, but the difficulty can be successfully met by very simple means. Some home-made batteries, constructed for the purpose of testing this matter, were made by slitting quarter-inch lead pipe lengthwise with a saw and building up a grid consisting of the narrow leaden troughs thus produced, one above another, until a framework of the desired dimensions was attained. These strips were held in place by casting around them a frame of lead. It only remained to fill the interstices of this rudely-constructed grid with the active material and subject the plate thus manufactured to the forming action of the current in order to make an excellent storage battery. The cells thus produced were given a long series of tests in the laboratory, for the purpose of determining the quality of their performance. It has been found that they compare favorably with the best types of storage cells now on the market in durability under widely different conditions of service, including heavy discharge and irregularity of service, such as is rarely expected of batteries in commercial use. The expense ac-

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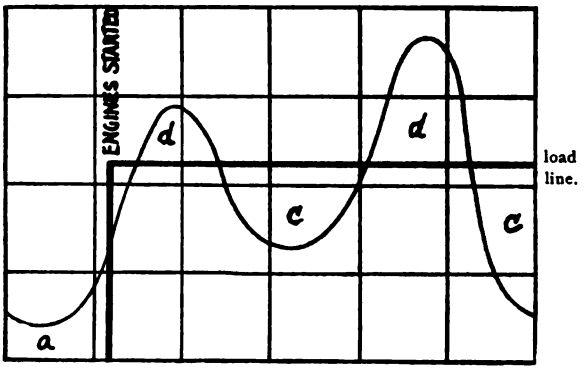
counts of making a battery of such cells, even without the appliances at the hand of manufacturers, show that the statement made in the opening paragraphs of this paper, namely, that the margin between the cost of raw material and of the manufactured product is in this industry of unwarranted size, was fully justified. Counting the price for labor at rates in excess of those which would be paid by manufacturers of such articles, and taking the cost of the raw material at the market price which the small purchaser has to pay, it was found that such cells could be turned out for less than one quarter of the price charged for such storage batteries as are upon the market in this country.



(a) Battery carries entire load.
(d) Battery carries peak of load.
(c) Battery receiving charge.

FIG. 1.

The most important function of the storage battery of the present day is that of supplementing a dynamo and steam plant in power and lighting stations. Nearly all such stations are compelled to work under conditions requiring a twenty-four-hour service with highly fluctuating load. Both for lighting and for power as applied to traction there are short intervals of time during which the load rises to values far above the average. These "peaks" on the load curve occur as a rule, both for lighting and street traffic, during the morning and evening. The two curves coincide or overlap so that a combined power and lighting ser-

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vice has no better distribution of load than either one taken by itself would have. Indeed, the combination serves rather to aggravate the evil. In both cases we have comparatively light load during the middle of the day and during the late hours of the night, and yet in ordinary stations of considerable size current must be maintained upon the line during these slack periods.

Numerous devices have been tried for the purpose of maintaining a reasonably high efficiency of operation of power and light plants under these adverse conditions. Of these the most successful by far is the storage battery. The nature of the problem may be most easily discussed by means of a diagram showing the load curve for such a station (Fig. 1). On this diagram I have indicated the distribution of work for engines and batteries in order to show the way in which it is possible by use of a battery of sufficient size to equalize the demands upon the steam plant.

It is obvious first of all that in order to carry the load during the hours of maximum demand, boilers, engines and generators must be of much greater capacity than that required for the average load of the day, unless they are supplemented in some manner. This means excessive expenditure of capital, and it means the running of steam engines under conditions of poor economy during the greater part of the day. By the introduction of a storage battery it is possible in many cases to cut the size of the boilers and engines down by at least fifty per cent., which is an important saving in first cost, and to run these engines and machines at full load during the whole time that they are in operation. This means further saving. The manner in which the storage-battery service is combined with that of the steam plant is as follows:

From midnight, at which time the engines are shut down, until 5 A. M., the storage battery, previously charged, carries the entire load. This allows an interval of five hours, during which the engines are allowed to rest, which is in itself a desirable feature of this system. At 5 A. M. the engines carry the load, and in addition charge the storage batteries up to the time when the load has reached a value equal to the full capacity of the steam plant. From this time on the storage battery shares the

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load with the engine, taking everything in excess of the above-mentioned value. When the load falls again after the passage of the peak of the curve below the full capacity of the engines the batteries are again charged. On the approach of the second peak they are discharged once more, carrying the excess of load. During the early part of the night there is again a time during which the load is rapidly decreasing, when they can be further charged. At midnight the engines are stopped and the storage battery carries the night load as before.

Another position in which storage batteries are found very useful is in sub-stations situated near the terminals of long trolley lines and other lines for distribution of power. It is obvious that by the location of such a battery of suitable size for the work, the amount of current which has to be conveyed to the distant point need never exceed the average load beyond that point, whereas without such a supplementary service the lead wires must be sufficient to carry the maximum load required at the sub-station. The saving in copper thus made goes a long way towards paying the expenses and maintenance of the battery. The manner in which such a battery is to be utilized in a sub-station is obvious. During times of light load the battery is charged by means of the excess of current. When the load exceeds the average, the battery supplements the current from the central station and obviates the necessity of overloading the lead wires.

As an equalizer of potential upon trolley lines with automatic devices for immediate charge or discharge of the battery with every fluctuation, excellent success has been had in a number of instances. It has been found in the case of the electric road at Zurich, Switzerland, where this system has been in vogue for a number of years, that storage batteries will stand up under the very irregular and exacting service required of them in such work in a satisfactory manner. The rapidity with which such a battery is alternately charged and discharged is shown in Fig. 2, which is a diagram covering a half hour of the record of the Zurich station.

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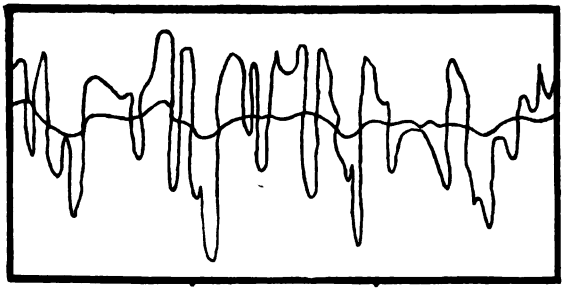

FIG. 2.

The very irregular line shows the variation for the station as a whole, while the nearly horizontal line shows the part carried by the engine. The storage battery is alternately charged and discharged to meet the demand of the moment.

Compared with the service demanded from storage batteries in the central and sub-stations and in isolated plants for light and power, the other uses are as yet comparatively insignificant. They are, however, very numerous, and taken in the aggregate would in themselves constitute a considerable industry. That these miscellaneous uses of storage batteries are on the rapid increase goes without saying, and that they may in course of time greatly exceed the uses described in the foregoing paragraphs is highly probable.—E. L. Nichols in the "Sibley Journal."

PRODUCTION OF IRON AND STEEL IN THE UNITED STATES.

According to the publication entitled "Statistics of the American and Foreign Iron Trades," for the year 1898, the production of iron and steel has greatly increased in the United States. In 1898 was witnessed the beginning of a movement in the iron trade of this country that has produced a revolution, the progress of which is being watched with the deepest interest by all exporting nations. This movement is no other than the consolidation of iron and steel firms, in order to create new corporations, which already control a capital estimated at more than $500,000,000.

From these statistics it is ascertained that the exportation of

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iron and steel and manufactures thereof in 1898 amounted to $82,771,550, against $62,737,250 in 1897, and against $48,670,218 in 1896, which shows an increase in two years of more than 70 per cent. Included in the exports of 1898 were 253,057 tons of pig iron, 291,038 tons of steel rails, 28,600 tons of ingots, blooms and billets, 18,510 tons of steel-wire rods, and 24,195 tons of other steel rods and bars, 27,075 tons of steel plates and sheets, 74,665 tons of wire, 15,735 tons of cut nails and spikes, 13,714 tons of wire nails and spikes, and 34,038 tons of structural iron and steel. There were also exported 580 locomotives and large quantities of machinery made principally of iron and steel.

In the above figures agricultural implements are not included, the exportation of which amounted in 1898 to $9,073,384, against $5,302,807 in 1897 and $4,643,729 in 1896. The importation of iron and steel by the United States has greatly diminished as a natural consequence of the enormous home production. Iron and steel, and manufactures thereof, were imported in 1880 in amounts aggregating $80,443,362, and were exported only in quantities valued at $15,156,703. In 1898 the amount of those articles exported represented a value of $82,771,550, and the importation of the same was valued at only $12,473,637, which shows that the conditions existing nineteen years ago have been entirely reversed.

The American manufactures of iron and steel compete favorably with the English, even in the domain of Her Bratannic Majesty. There are shipped to-day from the United States to England and her colonial possessions considerable amounts of pig iron, steel billets, steel rails, steel plates, structural steel, wire rods, wire nails and cast-iron pipe. Lately an order has been received for 60 American locomotives to be used on two of the great railways running from England to Scotland, the Midland and the Great Northern. As a remarkable fact we may add that the British Government has ordered in the United States a steel railroad bridge, consisting of seven spans 150 feet each, to be placed over the Atbara River in the Soudan. The Baldwin Locomotive Works, of Philadelphia, is now filling an order for 45 locomotives for railroads of India. The Pennsylvania Steel Com-

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pany has a contract for the construction of a steel viaduct, 2,260 feet long and 320 feet high over the Gokteik Gorge, in India. This work will cost $700,000. The Russian Government has ordered from the Phœnix Bridge Company, of Phœnixville, Pa., 12 steel railway bridges, etc., etc.

During the year 1898 the consumption of pig iron in the United States averaged a little over a million tons per month.

The exportation of iron and steel first exceeded the importation in value in 1893. Five years later, in 1898, the exportation of those articles exceeded the importation by $70,297,913.

In 1898 the exports of agricultural implements amounted to $9,073,384, against $5,302.807 in 1897. Mowers formed more than two-thirds of total value of these exports, for they alone represented $6,551,741.

The total production of pig iron in the United States during the year 1898 amounted to the enormous aggregate of 11,773,934 tons against 9,652,680 tons in 1897, which shows an increase of nearly 22 per cent. In the same year, 1898, the production of Bessemer steel ingots in the United States amounted to 6,609,017 tons.

The total weight of Bessemer steel rails in 1898 was 1,976,702 tons. The production of all kinds of steel in the same year was 8,932,857 tons.

It is estimated that the total consumption of iron ore in the United States during the year 1898 amounted to 21,193,000 tons.

THE BOILERS OF WAR VESSELS.

The "Engineer's Gazette," of August, 1899, thus alludes to the discussion of the boiler question for British war ships: There is no more important question at the present time in connection with the Royal Navy than that of securing durable, economical and safe boilers, which can supply high-pressure steam with rapidity without endangering their efficiency. Now all these requirements cannot be complied with by the ordinary marine boiler, and however much firms who have the requisite plant for making the "tank" boiler may be disinclined to hasten the adop-

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tion of water-tube boilers generally, they, as well as other less interested parties, are practically compelled to admit that it is impossible to revert to the use of the cylindrical boiler. While that is the case there still remains the very important question as to what water-tube boilers should be adopted. So far as the practice of the British Admiralty has gone the Belleville boiler has been solely adopted in vessels of large size, such as battleships and first-class cruisers, but there are not wanting signs that in this matter there will be a change and that other water-tube boilers will be adopted, free from "the great complications of detail and accessories" which was pointed out by Mr. F. T. Marshall in his paper on "The Boiler Arrangements of Certain Recent Cruisers," read at the recent meeting of the Institute of Naval Architects at Newcastle-upon-Tyne, to be one of the objections to the Belleville boiler.

The paper just alluded to is one of the most important contributions that has been made to the literature of the modern water-tube boiler, and while in it is to be found all that the writer could apparently see his way to state on behalf of the Belleville boiler, which has been manufactured under his direction and fitted by his firm on board of H. M. S. *Andromeda*, still to an unbiassed reader what he adduces against the Belleville boiler far away surpasses in importance any apparent advantages the boiler appears to have over water-tube boilers with fewer complications. He points out that a "grave objection" to the Belleville boilers "is the enormous mass of mechanical detail in connection with them. Thousands of joints, all dependent upon extreme accuracy of workmanship, and many of them subject to extreme strain, due to varying temperature, are a pronounced feature in the design of this type." * * * "The feeding is also extremely delicate, owing to the small quantity of water contained, and also to the variable weight of this water at different rates of evaporation. This latter condition necessitates the introduction of the hot-well pumps and large feed tanks. The feed regulator employed" is, Mr. Marshall truly says, "a delicate mechanism, and has to be kept in a high state of efficiency."

Referring to the large number of boilers necessitated in a vessel

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on account of the small size of the Belleville boiler, while admitting that subdivision of power was not without some advantage, he was compelled, on the other hand, to state, "but it certainly causes an enormous addition of important detail, such as feed-pipe and steam-pipe arrangements, all requiring care and attention," and that "the furnace air-pumping engines are also an additional complication, involving many extra fittings."

Now, while this paper was being read Sir John Durston, the leading engineering adviser of the Admiralty, was present, as was also a representative of the Belleville boilers' patentees, but in no way did they controvert what we have quoted from Mr. Marshall's paper. Sir John Durston practically confirmed the statements in it, as he described the comparison made in Mr. Marshall's paper as fair from the writer's point of view. There appears to be no reason whatever to imagine that Mr. Marshall has any interest antagonistic to the Belleville boiler; his "point of view" is to our mind that of a careful and skilled observer, and as such his views are of great weight.

It is unfortunate that the Admiralty have been committed to such an extent to the adoption of the Belleville boiler, and, naturally, that body will have great reluctance in acknowledging their error. Still, as we have already indicated, and not before time, there are signs that the Belleville will not remain the favorite water-tube boiler of H. M. Navy. The Chancellor of the Exchequer in his reply the other day to the strictures of Mr. Wm. Allen, M. P., defended the adoption of the water-tube as opposed to the cylindrical boiler, but not the Belleville as against all comers. The well-known engineer, Mr. Penn, after throwing out the suggestion of having on one vessel two different designs of water-tube boilers, one being of the small-tube type and capable of working under forced draft, and the other the Babcock and Wilcox, or other horizontal, straight tube type, concluded by hoping that the Admiralty would ultimately "adopt the best type."

Now it does appear that simplicity of design must be a feature in a permanently successful boiler, and it may now be safely affirmed that straight tubes are a *sine qua non*, whether they be

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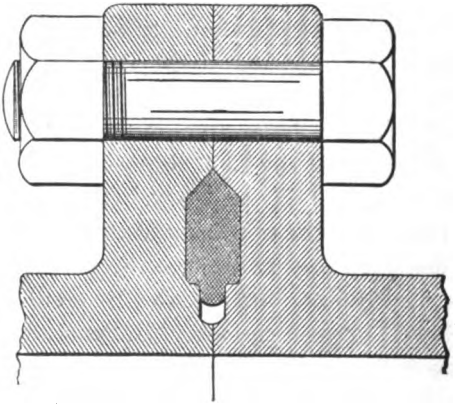
placed vertically or horizontally. In this respect the Yarrow, Babcock and Wilcox and the Belleville boilers may be said to be on an equality, but excepting this feature the latter boiler has no claim to be of simple design.

The fact that a series of tubes are connected together on an element, and if one tube be choked the circulation of the whole of that element ceases, is to our minds a fatal flaw in its design, and, together with the other complications to which Mr. Marshall directs attention, is sufficient to condemn it as a boiler for a British war vessel in the opinion of any unbiased engineer.

A PIPE JOINT FOR HIGH PRESSURES.

During the discussion of Mr. Nagle's paper on "Pipe Flanges and Their Bolts," at the recent Washington meeting of the American Society of Mechanical Engineers, the following remarks were made by Mr. Halsey. They show a novel and highly success-



CAPTAIN RAPIEFF'S PIPE JOINT FOR VERY HIGH PRESSURES.

ful form of pipe joint, and one which we believe has not before been brought to public notice.

"The sketch, which is made from memory only, shows a form of joint with which I became acquainted some years ago, and which was so satisfactory under trying conditions that it deserves to be more widely known. It was invented by Captain Rapieff

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for use with the dynamite gun—that is, the gun commonly known as the Zalinski gun. The joint was applied to the gun itself (which is in sections) and throughout the pipe fittings. The receivers are sectional with numerous connections, and positive tightness and reliability are essential. The firing reservoir, the gun and the intermediate connections operate under a pressure of 1,000 pounds per square inch, while the compressor, the storage reservoir and their connections operate under 2,000 pounds.

"The sketch shows a section of the joint. A groove of the section shown is turned in the face of each flange, a surplus or 'overflow' space being provided below. In the space formed by the grooves a strip of soft round rubber is inserted, the cross sections of the groove and rubber being so proportioned to each other that when the joint is closed the rubber will occupy part of the overflow space. The rubber used is not a continuous ring, but is cut from a long strip with a scarfed joint where the ends meet.

"It will be seen that the pressure coming down the joint drives the rubber into the angle at the top and that leakage is practically impossible. The grip of the bolts is not relied upon to retain the rubber by friction, as with the ordinary gasket. The joint is metal to metal, and the pipe sections may be gotten out to defined lengths—a feature that is occasionally useful. In the case of the gun, an additional feature of great value is that the tightening of the bolts does not, as with gaskets, tend to throw the sections out of line.

"As stated, this joint was used in a great number of cases, and I was assured that failure with it was unknown, positive tightness being expected and obtained as a matter of course."

MECHANICAL ENGINEERING AND SHIPBUILDING.

In his presidential address before the institution of Mechanical Engineers Sir William H. White, among other interesting points, drew a strong picture of the close relation which modern shipbuilding bears to mechanical engineering, showing how entirely the modern vessel, whether for war or for merchant service, is

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the product of mechanical operations and mechanical skill. Says he: "Mechanical engineering has intimate relations with all other branches of engineering. With none has it been more closely associated than with shipbuilding in recent times, and upon none has its influence been greater or more beneficial. The growth of our shipbuilding industry and the marvelous development of our mercantile marine during the last forty years are matters of common knowledge. The causes which have contributed to this supremacy are not so well understood and the part which mechanical engineering has played is not generally appreciated."

After enumerating the statistics of the growth of British shipping during the period indicated, and dwelling upon the changes wrought by the substitution of iron for wood and steel for iron, Sir William shows the contrast between an old-time shipyard and one fitted out with modern mechanical appliances.

"The contrast between former conditions and those now to be seen in a modern shipyard is extreme. Machinery and labor-saving appliances abound and are essential and economical. With ships of increased dimensions scantlings have become heavier, the sizes and weights of plates and bars have increased, special arrangements have to be made for transporting and handling materials, and the power of all classes of machinery has had to be increased proportionally. In a well-equipped yard the most careful consideration is given to every step necessary in dealing with materials, from their delivery up to the time when they find their places in the structures of ships. The stacks of plates and bars are so situated that the materials can readily be lifted from the trucks on arrival, or out of the depot when required for use."

The general use of traveling cranes and gantries is a matter of note, and the increasing employment of hydraulic and pneumatic tools, both for stationary and portable service, is also important. It is in the combination of all the multitudinous variety of machines and tools that the great influence of the mechanical engineer upon modern shipbuilding is seen, and it is not only the

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work of the mechanical engineer but also that of the electrician which has been utilized to the utmost.

"Electric power is being extensively used in some of the best equipped shipyards, apparently with satisfactory results. It is probable that the system will be much more extensively employed before long. For large machines with separate motors, and for groups of smaller machines, electric driving has much to recommend it. For operations that have to be performed *in situ* portable electric machines are found most useful. In some cases, especially in elaborately fitted warships, it is found advantageous to establish on board temporary machine shops, which can be most conveniently driven by electric power."

When it comes to the preparation of the material used by the shipbuilder the influence of the mechanical engineer predominates still more. Modern shipbuilding could not exist without the great progress which has been made in the manufacture of structural material.

"The shipbuilder is under great obligations to the steel maker for this progress in manufacture; but the mechanical engineer has had a hand in its achievement by designing and making the plant used in the steel works. In the device of new and more powerful machines for the shipyard his work has been more obvious. Without such machines the superior working qualities of steel could not have been utilized as is now done. Operations are now commonly performed on steel plates in a cold state that were not possible with the best qualities of iron."

In fact, all the long list of shipyard tools, including flanging, joggling, shearing and punching machines, as well as bending rolls, plate planers and all the better known machine tools are contributions of the mechanical engineer to the work of the shipbuilder.

On board the completed ship the work of the mechanical engineer is everywhere in evidence, from the propelling machinery, through the hoisting, lighting, ventilating and steering machinery down to the smallest and pettiest applications of power. On warships especially is the work of the engineer conspicuous, so

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much so that the modern warship is not inappropriately called a "fighting machine."

STRENGTH OF BOILERS.

The annual reports of the engineers to the great boiler and engine insurance corporations invariably provide matter well worthy of study. The reporters have opportunities of obtaining information as to the merits of different designs which no one in other positions, no matter how great their practice or experience, is able to command. It is a trite saying that failure teaches more quickly than success, and the instruction is certainly based on safer premises, since the margin of safety in a machine or structure which escapes failure is often uncertain. Bridges, for instance, have, under test, shown absolutely no sign of weakness when loaded with 90 per cent. of the weight which ultimately destroyed them, and the unreliability of the hydraulic test of a boiler taken *per se* is, or rather should be, a commonplace. That this fact is still not as generally recognized as is necessary, is unfortunately proved only too well by the evidence given in certain of the Board of Trade inquiries. That this test should be so untrustworthy is highly inconvenient; as, were matters otherwise, boiler inspection—now a particularly disagreeable job—would be both simplified and made more attractive. Still, as matters stand, successful resistance to such a test is no guarantee that the structure is not in a dangerous condition; and, similarly, in the daily working of an engine or boiler good fortune may for long mask the existence of an unsuspected weak point, which will be discovered only when the actual breakdown takes place.

In the nature of things, inspecting and insurance associations are mainly concerned in the morbid anatomy of the engines and boilers covered by their guarantee, and thus for one breakdown that comes under the notice of an ordinary manufacturing or consulting engineer, a dozen or more will be carefully investigated by the officers of such a corporation.

The former class, therefore, will always find much worthy of consideration in the annual reports of the latter, and the report

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just issued by Mr. Stromeyer, chief engineer to the Manchester Steam Users' Association, is no exception to the rule. In this report, Mr. Stromeyer has discussed at considerable length the collapsing pressure of flues, and has collected together particulars of many tests and of many failures. An empirical formula has also been devised by him, which fits these data fairly well. The formula is as follows:

Mean stress on plate at collapse, in tons per square inch =

$$3 + \frac{169{,}000}{13{,}000 + \left(\frac{L}{t}\right)^2}$$

where L represents the length of the flue and t the thickness, both in inches. With very short flues this formula gives the stress at collapse as 16 tons per square inch, whilst for very long ones the stress becomes 3 tons per square inch. Being an empirical formula, it should not, of course, be used outside of the special circumstances it has been designed to fit. Indeed, exception may justly be taken to the formula in that the stress at collapse is made to depend solely on the length and thickness of the flue, and not at all on its diameter. Thus, a tube 30 feet long, 1 foot in diameter, and $\frac{1}{4}$ inch thick would certainly carry a greater stress per square inch before collapse than one 3 feet in diameter, but of the same length and thickness. A ring near the middle of such a tube is exposed to a uniform compression, and thus closely resembles a column, and will finally yield by collapse in quite a similar way. The effective length of this virtual column is greater the greater the diameter of the flue, and the stress at collapse is correspondingly less for tubes of large diameter than of small, the thickness of the plate remaining constant.

The effect of stiffening rings and the like in increasing the collapsing pressure is of an indirect nature; and, in fact, it can easily be shown that within the elastic limit the action of such rings is actually to increase the maximum stress in the material of the flue. Professor Unwin has, however, pointed out that when a very long tube collapses, such tube, after deformation, has four points of contrary flexure, and hence the length of the virtual columns into which the tube separates is a quarter the

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total circumference. With shorter tubes the collapsed section exhibits more points of contrary flexure, thus shortening the length of the virtual columns, and consequently increasing the stress at which failure finally occurs.

For these reasons, therefore, Mr. Stromeyer's rule will require careful consideration before it can be accepted as of universal applicability, although it seems to accord extremely well with the results of experiments made here and abroad, the more especially when it is borne in mind that small geometrical errors of form or small local variations in the elastic properties of the material used may, in such experiments, have a disproportionate effect on the results.

ATOMIC WEIGHTS.

With the recent production by Professor Richards of a new table of the atomic weights of the seventy-four elements, the question of a revised international standard table is once more agitated.

At present there are at least seven tables of atomic weights in general use, namely, the governmental, compiled by Mr. Clarke; the more recent tabulated results of Professor Richards, of Harvard University, and the well-known standard weights of Berlin, Meyer, Scubert, Ostwald and Van der Plaats. As there are no two of these tables alike, much clamor arises because of discrepancies resulting when any two of these tables are consulted for reference.

A practical illustration of this occurs in the importation of chrome iron ore from Europe. In Europe the general atomic weight taken for chromium is 52.5, based on the ancient work of Berlin, a table used by many of the European analysts. In this country the more recent table of Mr. Clarke is the authority. This one takes 52.1 as the atomic weight of chromium. Thus a discrepancy of $367.50 on a cargo of 2,500 tons of this ore occurs when it is assayed in Glasgow and then again in the United States. Should the still more recent results of Professor Richards be taken, namely, 52.14, the variation would be but $330.95 on a cargo. Thus it is seen that even the apparently slight dif-

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ference of four parts in a hundred, which for practical purposes would seem unimportant, causes a loss or gain, either way you wish, of $36.55 on a single cargo. Of what enormous value to dealers would be a standard international table of atomic weights, whereby each cargo would have the same relative value whether assayed in Europe or America.

The labor involved and the accuracy and skill required to compile a table of atomic weights is very great, so difficult that even some of the best of chemists refuse to spend their time and risk their reputation in performing this task.

The stupendousness of the work can be slightly conceived when one realizes the minuteness of an atom. The atom is defined as the smallest particle of matter, and is believed to be incapable of division into parts. These particles are so small that they cannot be observed even under the most powerful of microscopes, and so solid that they cannot possibly be broken or abraded by any concussion or violence whatsoever. To each of these atoms, however, a certain so-called atomic weight has been assigned; that is, a relative weight of the atoms, or the proportions in which they unite.

Certain of the well-known tables are constructed on the assumption that the atomic weight of hydrogen is 1. With this as a basis, the atomic weight of oxygen is determined as slightly more than 16. Others assume the atomic weight of oxygen to be 16, and in a table constructed on this basis the atomic weight of hydrogen is found to be slightly less than 1. Thus these two tables will vary slightly in all of the determinations.

This fact, however, is not the only cause for discrepancy in the different standard tables; indeed, it is probably the cause of only the slighest variation.

The principal errors in the determinations result from imperfect mechanical separation, crystallization and ignition, due to the partial solubility of nearly all precipitates and containing vessels, and also to the occlusion of foreign matter in crystals, oxides and other substances. Although these errors are carefully weighed and considered and allowances are made for them, it nevertheless stands to reason that as all of the tables are en-

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tirely independent of one another, or nearly so, there will still be discrepancies between them.

Name.	*Symbol.*	*At. Wgt.*	*Name.*	*Symbol.*	*At. Wgt.*
*Aluminium,	Al.	27.1	Molyddenum,	Mo.	96.0
Antimony,	Sb.	120.0	Neodymium,	Nd.	143.0
Argon,	A.	39.9	Nickel,	Ni.	58.20
Arsenic,	As.	75.0	Niobium,	Nb = Cb.	94.0
Barium,	Ba.	137.43	Nitrogen,	N.	14.045
Beryllium,	Be = Gl.	9.1	Osmium,	Os.	100.8
Bismuth,	Bi.	208.0	Oxygen (standard),	O.	16.0
Boron,	B.	10.95	Palladium,	Pd.	106.5
Bromine,	Br.	79.955	Phosphorous,	P.	31.0
Cadinium,	Cd.	12.3	Platinum,	Pt.	195.2
Caesium,	Cs.	32.9	Potassium,	K.	39.140
Calcium,	Ca.	40.0	Praseodymium,	Pr.	140.5
Carbon,	C.	12.001	Rhodium,	Rh.	103.0
Cerium,	Ce.	140.0	Rubidium,	Rb.	85.44
Chlorine,	Cl.	35.455	Ruthenium,	Ru.	101.7
Chromium	Cr.	52.14	Somarium,	Sm.	150.0
Cobalt,	Co.	59.0	Scandium,	Sc.	44.0
Columbium,	Cb = Nb.	94.0	Silicon,	Si.	28.4
Copper,	Cu.	63.60	Sodium,	Na.	23.0
Didyium,	Nd + Pr.	142.0	Sulphur,	S.	32.065
Erbium,	Er.	166.0	Selenium,	Se.	79.0
Fluorine,	F.	19.05	Silver,	Ag.	107.93
Gadolinium,	Gd.	156.0	Strontium,	Sr.	87.68
Gallium,	Ga.	70.0	Tantalium,	Ta.	183.0
Germanium,	Ge.	72.5	Tellurium,	Te.	127.5
Glucinium,	Gl = Be.	9.1	Terbium,	Tb.	160.0
Gold,	Au.	194.3	Thallium,	Tl.	204.15
Helium,	He.	4.0	Thorium,	Th.	233.0
Hydrogen,	H.	1.0075	Thulium,	Tu.	170.0
Indium,	In.	114.0	Tin,	Tn.	119.0
Iodine,	I.	126.85	Titanium,	Ti.	48.17
Iridium,	Ir.	193.0	Tungsten,	W.	184.4
Iron,	Fe.	56.0	Uranium,	U.	240.0
Lanthanum,	La.	138.5	Vandlium,	V.	51.4
Lead,	Pb.	206.92	Ytterbium,	Yb.	173.0
Lithium,	Li.	7.03	Yttrium,	Yt.	89.0
Magnesium,	Mg.	24.36	Zinc,	Zn.	65.40
Manganese,	Mn.	55.02	Zirconium,	Zr.	90.5
Mercury,	Hg.	200.0			

* "A New Table of the Atomic Weights of the Seventy-four Elements." Presented before the American Society of Arts and Sciences, March 9th, 1898, and published in the "American Chemical Journal" of July, 1898. Complied from the most recent data by Prof. Theodore W. Richards, of the Chemical Laboratory of Harvard University.

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In the above table compiled by Professor Richards, all of these facts have received due consideration and allowances have been made for them. Chemical and mathematical errors have been eliminated so far as possible, and in every way he has striven to make the table as accurate and complete as possible, but at the same time practical. Neither has this table been compiled independent of the other standard tables. In each determination comparison has been made with the best. In some cases, such as those of the rarer metals, where sufficient data could not be obtained to insure the correctness of the one or the falsity of the other, a compromise has been made, and the mean between the two decided upon.

In a comparison between Mr. Clarke's and Professor Richards' tables, the results are seen to agree very closely. Only in about seven determinations is there found any appreciable discrepancy. In these cases, namely, the weights of antimony, cadmium, calcium, magnesium, platinum, tungsten and uranium, however, the new figures of Professor Richards find preference, first, perhaps, because of the more recent methods and improved determinative processes used, and, secondly, because of his reputation as a chemist and metallurgist. As these tables are to-day used by chemists and metallurgists in every assay and analysis the discrepancies between them, especially between the seven elements mentioned, are of no little importance.

To have one, and only one, standard international table compiled by a committee composed of the eminent chemists of the world, would be hailed by all kinds of chemists and dealers alike, as an epoch in the history of chemistry. Means, appliances, the best of specimens and the more recent data would be at their disposal, and, together with the accuracy and skill of the committee themselves, should result in the production of a table that would be far more accurate than any yet produced. It would undoubtedly meet with universal approval and would eliminate the present confusion, caused by the numerous so-called "standard" tables on the market to-day.—W. H. Swenarton, in "Yale Scientific Monthly."

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NEW SYSTEM OF FORCED DRAFT.

[Extract from a paper by Mr. Nelson Foley, read at a recent meeting of the Institution of Naval Architects.]

The writer has called the system about to be described new, believing it to be original and, up to the present, untried, except by himself; but he is naturally open to correction, should such not prove to be the case. The fundamental principle of the system is that the fire bars themselves are utilized as a means of forcing the air into the fire. In order to accomplish this, these bars are made hollow, and are perforated with a row of small holes along each side near the upper surface, the holes being placed at such an angle that the air is forced in jets into the fire through the ordinary spaces between the bars. The front ends of the bars are inserted into a box or canal under the fire door, which is in communication with a fan.

Without being sanguine of a satisfactory result, it was thought that the benefits to be gained in leaving both stokeholds and ashpits open were sufficient to justify some experiments being made on a small stationary water-tube boiler. The results have been so far beyond expectation that the subject appears to the writer to be of sufficient interest and importance to warrant his bringing it under the notice of the Institution; in fact, it seems to him to bid fair to cause some revolution in forced combustion. The results of these experiments are appended at the end of the paper.

Up to the present only short bars have been experimented with, but a sample bar up to 4 feet in length has been cast without difficulty; at the same time, where it is possible to have an air box at each end of the grate, the bars need never exceed the moderate length of, say, 3 feet. A method of uniting them in the center has always been devised for such cases as when the front only is available for an air box and a long grate is desired. It should be noted, however, that it is thought preferable, in order to give facilities for good stoking, cleaning fires and keeping the fires in good order, to work always with short grates and use a high rate of combustion. It has been observed during the experiments that little refuse falls into the ash pits, that the bars keep perfectly cool and that the clinker does not adhere to

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them; in fact, from time to time the clinker can be removed from the fire without drawing the same. It has also been noticed that during forced draft the bars do not suffer at all, although it is only fair to say that on one occasion the ends of some of the bars were burnt because the bridge at the back was not in order, a space being left between it and the bar ends. The bars have been tried at natural draft, and after ten days' continual steaming during day hours, no more than the normal injury was sustained, and only a few holes were found choked.

It is intended, in adopting this system, that the full advantage should be taken, making the grates moderate in length, and running with forced combustion as a normal condition. In this matter the destruction of fire bars would be reduced to a minimum, and the fires could be regulated to a nicety. The fire can be regulated also, so that it is a matter of indifference whether the fire door is open or shut; but, of course, it cannot be overlooked that, at very high rates of combustion, especially with ordinary cylindrical boilers, the fire door must be kept shut, as with the ordinary ash pit draft. Presuming a long life for the individual bars, the cost of production need not, it seems to the writer, be considered a serious matter; for the foundry in Naples it comes to about 10 centimes per kilogramme.

RESULTS OF FORCED-DRAFT EXPERIMENTS.

Experiment.	Air pressure.	Coal, lbs. per hour per sq. ft. of grate.	Jet holes.		Bars.		Observations.
			Diam.	Pitch.	Length.	Surface.	
	ins.		*in.*	*in.*	*ft. in.*	*sq. ft.*	
1	1.38	29	$\frac{5}{32}$	$\frac{11}{16}$	2–7½	7	Evap. trial, careful firing.
2	1.45	32	$\frac{5}{32}$	$\frac{11}{16}$	2–7½	7	Evap. trial, careful firing.
3	1.25	41	$\frac{5}{32}$	$\frac{11}{16}$	2–7½	7	For combustion only.
4	1.73	40	$\frac{5}{32}$	$\frac{11}{16}$	2–7½	7	Evap. trial, careful firing.
5	3.15	72	$\frac{3}{16}$	$\frac{11}{16}$	1–3½	3.22	For combustion only.
6*	3.15	53	$\frac{3}{16}$	$\frac{11}{16}$	2–7½	7	Evap. trial, careful firing.

* During this trial it was thought that for this rate of combustion the passages to the funnel were too contracted. On measuring the same they were found to be collectively between one-sixth and one-seventh of the grate area, whereas the funnel area itself was one-fifth.

The experimental grate was 2 feet 7½ inches long and 2 feet 7½ inches wide; in the case of experiment No. 5, however, half

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the length was bricked over. The air pressure was obtained from a smithy blast, the strength of which was never more than 80 millimeters ($3\frac{1}{5}$ inches). Coal was of the Cardiff kind, of good quality. Height of funnel from bar level, 17 feet 6 inches.

POWER REQUIRED BY MACHINE TOOLS.

In determining the power consumed by machine tools when operating under various conditions it is customary to measure the power required when running empty and deduct this quantity from that used when performing work. That this method is not exactly correct has long been known, since it it evident that the friction of the machine itself cannot be the same in the two cases, but it has been assumed that the error from this cause was not great enough to be of material consequence.

In the course of a recent series of experiments to investigate the power consumed by metal-working tools, MM. Huillier and Fremont made an interesting calibration of the dynamometer used, in connection with various determinate degrees of resistance at the machine, and thus were enabled to take the increased friction of the tool into account. A very full report of these valuable trials upon a number of tools is given in the "Bulletin de la Société d'Encouragement pour l'Industrie Nationale," the whole forming an important contribution to this branch of technical knowledge. The variations in frictional resistance were made by delivering the power of the tool, a lathe for example, through a recording dynamometer of the Morin type, while various resistances were opposed by means of a Prony brake acting upon a pulley on a mandrel turned by the lathe. If the frictional resistance of the lathe had remained constant, the differences between the brake and dynamometer readings should have continued uniform, while any variations between the two measurements indicated the variation in the resistance of the lathe. By plotting the results of a number of such tests it was demonstrated that the friction of the machine increased directly with the resistance, being, in the case of a large lathe tested, equal to 16 per cent. of the added resistance on the brake. This

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coefficient of 16 per cent. varied somewhat according to conditions of lubrication, temperature, etc., and similar coefficients should be determined for different groups of machines before making extended tests.

In conducting their further trials upon the resistance of machine tools, MM. Huillier and Fremont adopted the method of measuring by the dynamometer the amount of power delivered to the machine and taking the effective work from the pressure exerted at the cutting point of the tool. In order to measure the actual pressure at the tool, an ingenious form of dog was devised, of which detailed illustrations are given in the original paper. In the usual method of working the dog is clamped firmly to the work to be revolved in the lathe, and is also engaged positively with the face plate, the work being thus pushed around by the force applied to the plate. In these experiments, however, the dog is so arranged that it is pulled around instead of being pushed, and, being connected to the work by a spring arm, the effort required to revolve the piece against the fixed resistance of the cut is measured by the deflection of the spring. An ingenious system of levers transmits the deflection of the spring, as it revolves, to a fixed recording card, and, the leverage being known, the resistance of the tool at the cutting point is recorded continuously. When to this is added a simultaneous record of the speed of the surface upon which the cut is acting, all the data for the computation of the power exerted are determined. Another factor, which although not essential to the measurement of the power is of interest in connection with machine design, is the direct pressure required behind the tool for a given depth of cut. This was determined by a special pressure device fixed upon the slide rest.

Before proceeding to the use of these devices they were carefully calibrated by the direct application of weights, and the proper factor determined, so that reliance might be placed upon the corrected readings, the deflections only being measured and the corresponding pressure computed.

In the application of these devices some interesting observations were made. During a continuous cut, as in the turning of a

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shaft, for instance, the resistance was by no means uniform, varying in the case of a shaft 92 millimeters in diameter, from 270 to 337 kilogrammes. This variation may be attributed to two causes: the lack of homogeneity in the metal and the breaking of the turnings. The unequal hardness of the material was evident, and it was easy to observe that variations in pressure on the tool occurred periodically as certain portions of the shaft came under the tool; the breaking of the turning could also be seen to affect the record of resistance. Making allowance for these variations, by taking the mean resistance for a continuous run and weighing the quantity of metal removed in the form of chips and turnings, a very complete record of the performance of various tools was obtained and tabulated.

In the paper above referred to the effort was made to determine more especially the power required by the various machines, and hence the conditions of the cutting tools themselves was maintained as nearly constant as possible, but in subsequent researches it is intended to vary the cutting angles, depth of cut, and similar conditions, and thus make practical comparisons. The present paper contains data from twenty-one different machine tools, giving for each machine the following data: speed of belt, pull on belt, power delivered, speed at the cutting point, weight of chips produced per hour, and net amount of work required to produce one kilogramme of chips, the tools including a variety of lathes, milling machines and drill presses.

THE BOOM IN STEEL AND IRON.

There is no doubt that the principal cause of anxiety among those who have studied the conditions of the present era of prosperity in the United States is as to the ability of obtaining an adequate supply of steel and iron, which lie at the very basis of industrial activity in the present age, and emphatically so in the line of shipbuilding. When we read that although the production of iron and steel is the largest on record, that the importation of iron ore is also exceeding the record, but still inadequate to the demand in spite of the increased output of

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native ores also, and that Germany is coming to us to buy pig iron, it can readily be seen that the situation is not only unique, but a cause for apprehension. While Pennsylvania plants are obliged to work to their fullest capacity to fill the orders already booked, word comes from Alabama that furnace men at Birmingham are canceling orders for pig iron because there is no product to supply the demand. It is stated that orders enough will be placed within six months to keep furnaces busy all next year. Meantime in some shipyards keels are laid for which it is impossible to get iron or steel to make headway in construction, and some builders are in consequence declining to agree to any time limit as to further contracts.

The record of pig iron output shows that the largest tonnage in the history of the United States was produced during July, the estimated weekly output having been 269,032 gross tons per week, which was an increase of 12,154 tons per week over the output of June, and that month had 1,689 tons per week of a greater output than any previous similar period. Nevertheless the demand increases faster than the ability to produce. Some furnaces will not take orders for next year yet, and prices for delivery during the first half of 1900 are quoted by only a limited number of producers. The fact that our last year's product exceeded by ten per cent. our previous maximum and is already far in advance of the output of Great Britain, adds to the peculiarity of the position.

The outlook for the industry is one dependent in great degree upon the careful management of those in charge of the great fundamental businesses for continued success. If there are no strikes, and if other nations do not overtake us, as there seems no probability of any of them doing, the United States will lead the world next year in this most important line of activity. Besides the demand abroad for our finished products of steel, such as bridges, rails, railway materials, machinery, etc., which our contractors must fill, our shipyards must be supplied with the necessary steel to keep their plants going, and these must become prior demands upon steel manufacturers. If smooth working in all the contiguous lines of this industry continue,

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therefore, our nation is certainly booked for a long continuance of unparalleled prosperity.—Ex.

THERMODYNAMIC ACTION OF "STEAM GAS"

One of the most valuable papers recently published in the field of applied sciences is that which has been just reprinted from the "Revue de Mécanique" of the last year, the work of Professor Sinigaglia, of l'École des Ingénieurs de Naples, a well-known author in the field.

This is the latest and, in many respects, the most complete discussion of a supremely important subject, one to which the minds of men of science and engineers the world over are now again turning after a period of many years, during which thermodynamic promise of gain in efficiency in the steam engine through the conversion of a vapor into a gas by this process of superheating had been almost universally believed to be more than counterbalanced by the very serious difficulties met in the earlier days in the attempt to profit by it. Changes have taken place during the last generation which are now thought by many authorities to have largely reduced the obstructions formerly seemingly fatal to the great thermodynamic advance.

In the practical thermodynamic operation of the steam engine, as M. Bertrand has remarked, there is no such thing as "saturated vapor," as that term is customarily employed by the thermodynamists. The working fluid is always, in fact, a mixture of vapor and its liquid in a state of instability as to quality. The investigations of the "*théorie générique*" made by Rankine Clausius, Zeuner and others resulted in establishment of no rational expressions for the actual heat exchange of the real, as distinguished from the ideal, engine, and Hirn's "*théorie expérimentale*," as developed by that great investigator and his disciples, is still the only resort of the student of the curious extrathermodynamic processes accompanying the thermodynamic operation of the engine.

Supherheating has come to be looked upon, not as a method of giving superior thermodynamic action, but as simply a pro-

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vision for reducing internal wastes due to heat exchanges between the steam and the metal surrounding it. Its effectiveness was recognized as early as Trevethick's time (1828 or earlier), and became well understood about the middle of the century; since which time numerous inventions have been made looking to its utilization; few giving any promise of success. The Alsatian school has revealed very completely the method and the effect of its adoption, and it has come to be well understood that its province is simply to reduce that form of waste known as "initial condensation" or "cylinder condensation." Its successful use would affect the suppression of those losses in such manner, in the words of Dwelshauvers-Dery, as to give maximum efficiency by securing the exhaust of the steam from the engine in the dry and saturated condition. This is, in his opinion, the practical criterion of most perfect action. The actual gain has been found by Hirn to be, in several cases studied by him experimentally, from 20 to nearly 50 per cent., with a superheat amounting to from 210 degrees centigrade to 245 degrees centigrade. The nearest approximation yet reported to the ideal, purely thermodynamic case has been affected by this means—particularly of late by Schmidt.

The failures of the past have been due to difficulties in securing an apparatus which cannot be rapidly injured by excess of heat, in presence of superheated vapor of water, and a system of lubrication of the cylinder and piston capable of working satisfactorily at the temperatures attained in effective superheating. The latter obstacle is now overcome, largely by use of the high-test mineral oils; the former remains a serious obstruction. The increasing steam pressures of our day also reduce both the need and the availability of increasing superheat.

The results of successful superheating exhibit themselves both at the engine and at the boiler, and, as with multiple-cylinder engines, the gain at the boiler in economical employment of fuel is greater than that at the engine through a more perfect thermodynamic action; for the reduction of the demand for steam at the engine results in an increased economy in the production of such steam through the larger proportion of heating

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surface to weight of steam produced. Thus a gain of 20 per cent. at the engine may be accompanied by a gain of 22 per cent. or more in fuel as measured at the boiler. The desirable amount of superheat is that which will prevent the condensation of the vapor entering the steam cylinder and insure its rejection as saturated vapor at exhaust.

The apparatus employed by various inventors and investigators in this field, from 1850 to our own time, is described at considerable length by M. Sinigaglia, and the results of experiment are recited. In many instances, recently, particularly, it is reported that no serious inconveniences were met with in the application of this system; in other cases much trouble and sometimes serious accidents resulted, due to the "burning" of the apparatus and its yielding, thus weakened, to the pressure. Messrs. Ludwig and Weber obtained, in an extensive series of experiments in Alsace, some very encouraging figures. An average gain of 7.5 per cent., net, was secured by moderate superheat (44 degrees centigrade). Messrs. Walther-Meunier, and Ludwig later, reported a gain of 13 to 15 per cent. from a superheat of somewhat greater amount. Schwoerer obtained a gain in efficiency of 15 to 18 per cent. by superheating 68 degrees centigrade. Hirsh reports similar figures from an equal amount of gasification in a marine apparatus. Schroeter obtained gains of 10 per cent. and more in a very elaborate and detailed investigation, in which the superheat amounted to 60 degrees centigrade. The most remarkable results reported are those of Schmidt, who, by adopting an enormous proportion of superheating to heating surface (six to one), secured a superheat of 190 degrees centigrade, and at another time, with a comparatively small apparatus, secured the highest record yet established. With another engine a gain in weight of steam supplied the engine, amounting to nearly 40 per cent., was effected, and in weight of fuel, 28 per cent.; the difference being due, obviously, to the fact that each unit weight of steam carried an abnormal quantity of stored heat.

Professor Sinigaglia concludes:

1. Superheating vapor is proved irrefutably to be the most

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effective system of reduction of internal wastes of heat in the steam engine.

2. The higher the degree of superheating attainable, the nearer does the thermodynamic result approximate that indicated by pure theory and by the formulas of thermodynamics.

3. From the industrial point of view, it is necessary to note the gain, not at the engine, but in fuel demanded at the boiler, and the apparatus of vaporization and of gasification must be efficient and durable.

4. The final test is in the study of the financial aspect of the operation.

"But, to-day, the numerous installations in Alsace and Germany have given such remarkable results that the end will be that they will overcome the last difficulties which oppose a general application of superheating to steamships. This will be the best homage paid to Hirn and his school."—R. H. Thurston, in "The Sibley Journal of Engineering."

NOMINAL EFFICIENCIES OF MACHINERY.

Without straining after the sensational by purloining upon the precincts of the impossible, it suffices to direct attention to the enormous wastefulness of the processes upon which we are dependent at the present day for the great bulk of our useful mechanical power. Nearly all of this power is developed in steam engines, and these, although marvels of ingenuity, are exceedingly wasteful means of transforming chemical into mechanical energy. The efficiency of boilers is fairly good, being not unfrequently 80 per cent.; but the efficiency of the best engines scarcely exceeds 20 per cent., and, in fact, this efficiency is only reached in comparatively rare instances. The combined efficiency of engine and boiler, with reference to the heat energy in the coal, is, therefore, rarely as high as 16 per cent. Strictly speaking, of course, the best engines should not be regarded as wasting 80 per cent. of the power they receive, since an ideally perfect heat engine would, under the same conditions, only be

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capable of utilizing about 35 per cent., so that the efficiency of the best engines is nearly 60 per cent. with reference to the behavior of ideal heat engines working between the same limits of temperature. When we consider, however, that engines in common practice give results considerably below these figures, and commonly deliver only about 5 per cent. of the energy resident in the coal they burn, it is evident that enormous room for improvement exists in the direction of transformation of energy.

The efficiency of refrigerating machines is practically the only efficiency which is commonly stated as being in excess of unity, or 100 per cent., and is, therefore, an apparent exception to the general rule that an efficiency may not be greater, and is usually appreciably less, than 100 per cent. In some cases the efficiency of an ammonia refrigerator expressed as the ratio of the heat energy withdrawn from the refrigerating room to the mechanical energy expended by the compressor in the process is over 4, i. e., over 400 per cent. This high nominal efficiency has sometimes led to the erroneous belief that refrigerating plants were capable of practically creating energy. The reason for this high nominal efficiency of the refrigerator lies in the fact that under acknowledged thermodynamic law some four units of heat energy have to be transferred from a furnace at the temperature of 100 degrees centigrade to the cooling chamber at a temperature of 7 degrees centigrade, in order to liberate 1 unit of mechanical energy in a perfect engine working between the two. In other words, the theoretical efficiency of the engine would be only about one-fourth, or 25 per cent. But all perfect heat engines are reversible. It therefore follows that if the operation of such an engine were reversed each unit of mechanical energy supplied to the engine would bring about the transfer of 4 units of heat energy from the cold chamber to the hot chamber, or the efficiency of the process would be 400 per cent. But, of course, this high efficiency is of no practical value in the production of mechanical power, since on again reversing the engine it would take 4 such units of heat energy to give out 1 unit of mechanical work. This use of the word efficiency in regard to refrigerators, unless carefully defined, is unfortunate.—"Electrical World."

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FLANGING HEAT FOR STEEL PLATES.

The importance of the working of boiler sheets in flanging at temperatures above the "blue heat" does not appear to be generally appreciated, although it has been known for years that steel worked too cold receives permanent injury which is likely to cause it to fail under stresses that are far below its normal strength. This was one of many valuable points brought up for discussion by Professor Hibbard's paper on locomotive boilers, recently read before the New York Railroad Club, and it will pay those who make or repair boilers of any type to examine their practice in this regard. Flanging is a difficult operation, especially when performed by hand without the aid of special formers. The work is naturally slow and the tendency to use as few heats as possible is strong. The result of this is to work the sheets as long as possible after each heat, and frequently the temperature falls until the metal receives permanent injury, even before it has been put in place in the boiler. The ideal method of forming and flanging boiler plates is to use large furnaces, heating the entire sheet at once, and then, by the use of hydraulic presses and dies, to press the sheet into the desired form at a single operation. This, of course, requires a large outlay for special machinery and dies, which small establishments cannot afford. The smaller sectional hydraulic flanging presses are available, however, and large dies are not needed with these. The work is not as rapid as with the large presses and the danger of working at the blue heat is greater. A satisfactory rule for judging of the temperature below which the work should not be done is to rub a piece of wood over the surface of the plate, and if it does not leave a red glowing path the sheet is too cold and the work should stop. The necessity for increased care in this connection is more apparent with the increase in steam pressures, and by insisting upon this simple rule in the boiler shop a great deal of anxiety may be avoided. The "blue heat" occurs between temperatures of 550 and 700 degrees and is below the temperature at which iron will show a red glow in the dark. Its most prominent effect seems to be to reduce the ability of steel to resist repeated bendings, and the life of

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modern locomotive boilers depends very largely upon this quality. A sheet which has undergone this treatment will withstand only about one-third as many bendings as before.—"American Engineer and Railroad Journal."

POSSIBILITIES OF THE TURBINE.

A subject of general interest in the field of marine engineering just now is the derivation of power for vessel propulsion from steam turbines. Discussion of this force heretofore presented has been open to doubt, not only on the score of authenticity of the assertions made, but also from question as to the reliability of the source of information. Especial value therefore attaches to an article on the subject in the current issue of "Cassier's Magazine" by Hon. C. A. Parsons, of England, inventor of the type of turbine bearing his name, and the builder of the *Turbinia*, the first vessel to which this force was applied.

Mr. Parsons deals at the outset with the first problem which presented itself to him, that of constructing a steam turbine of good steam economy and with a comparatively moderate speed of revolution, so as to permit of its being coupled directly to a dynamo. Some of the advantages claimed for steam turbines over ordinary engines are the small space occupied, light weight, low first cost, reduced upkeep and attendance, better governing, together with the fact that no expensive engine foundations are required. Mr. Parsons is emphatic in the declaration that the most important field for the steam turbine is in the propulsion of ships, by reason of the imperative necessity for some form of engine which shall be light, capable of perfect balancing and economical in steam. The disappointments which followed the construction of the *Turbinia* will be full of interest for marine engineers generally. They were induced, of course, by the speed, which was so much slower than had been anticipated as to make it apparent that there was some radical defect in the propellers. How it was discovered that there was an insufficiency of blade area, or that, in other words, the water was torn into cavities behind the blades—cavities which contained no air

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but only vapor of water—has heretofore been detailed. On the obviation of all vibration so pronounced in all other fast vessels, however, Mr. Parsons lays considerable stress. The economy of engines is also demonstrated, he says, by actual figures, the consumption of steam per indicated horsepower for all purposes at 31 knots speed being given as 14½ pounds, or, in other words, with a good marine boiler the coal consumption would be considerably under 2 pounds per indicated horsepower. At a recent trial to test the endurance of the machinery it was demonstrated that the *Turbinia* can maintain a speed of 30 knots for three hours.

The information is given that each of the torpedo-boat destroyers of the *Turbinia* kind building for the British Government, and which have been previously referred to in the "Review," will be fitted with turbine engines of 12,000 horsepower. In the case of these vessels, as with the *Turbinia*, the great claim is relative to the saving of weight, the horsepower per ton of total weight of machinery including boilers in working trim being in the case of the new turbine-equipped vessels 75 as compared with 48 in the case of ordinary engines. Although the claim is made that the turbine engine offers many advantages to the naval architects of Atlantic liners, it is admitted that the highest speeds will be attained by short-passage vessels.

Perhaps the most interesting feature of Mr. Parson's article is his final observation. He says: "In conclusion it may be interesting to give a few particulars as to what may ultimately be reached in fast-speed, unarmored cruisers of moderate size, though doubtless it will take some courage to enter upon the construction of such a vessel. Still, something like this will probably be attempted before long: A vessel of 3,000 tons displacement, 450 feet in length, 42 feet beam and 14 feet maximum draught of water, carrying turbine engines and boilers of 120,000 maximum horsepower, the boilers being of the water-tube type arranged in two tiers. This vessel could steam economically at 16 knots speed, but would, in emergency, be capable of increasing her speed to 48 knots and maintaining this speed for three hours; or she could maintain a speed of 45

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knots for eight hours. She would be difficult to hit with shot, and her speed being 18 knots greater than that of any locomotive torpedo, she could take her chance in this respect. A few such vessels would be of immense tactical value to a squadron in time of war."—" Marine Review."

MISCELLANEOUS.

GASOLINE ENGINES.—The remarkable progress which gas and gasoline engines are making is a natural result of education in regard to their advantages. The best of steam engines used for ordinary work consume about 2 pounds of coal per horsepower hour and from 6 to 12 pounds more nearly represents common practice with small steam engines. The cost of attendance for a steam plant is very high and proportionately higher per horsepower as the size of the engine decreases. A steam boiler requires constant nursing, frequent cleaning, scaling and overhauling, and also these expenses are constant, even if the engine is used but a few hours each day. The internal-combustion engine presents an agreeable contrast to all this. It starts easily and quickly, and when once started it needs only to be oiled and properly loaded to work along unattended all day long. The fuel consumption is proportional to the load, and when the engine stops all expense stops also. As to the relative cost of operation, it may be confidently accepted that a gasoline engine will cost not more than half as much to run as a steam engine of equal power. The time has come for the gas engine to receive careful consideration by all who contemplate enlarging or remodeling old shops, and especially by those who are planning new ones. The new Westinghouse works for the manufacture of air brakes in Russia are to be driven entirely by gas engines. Why should they not be used for driving the machinery of railroad shops? They offer a most satisfactory method of distributing power, and there are many designs that are quite ready for important responsibilities.—"American Engineer and Railroad Journal."

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MOST INTENSE HEAT YET OBTAINED.—The heat of the electric furnace, which is due simply to an electric arc enclosed in a closed crucible of incombustible material, is the greatest that can be obtained artificially. When this was run up to about 6,300 degrees Fahrenheit by Professor Moisson it was thought that the limit had nearly been reached; but Professor Tucker, of Columbia University, has "beaten" the French professor by several hundred degrees, we are told by "Electricity." An interesting result is that whereas the artificial diamonds that could be made in Moisson's furnace—perhaps its most interesting products—were exceedingly small, much larger stones have been produced in the improved Tucker furnace. Says "Electricity": "Some time ago Professor Moisson, by means of a specially-devised electric furnace, succeeded in making artificial diamonds, the largest, however, not measuring much over forty-thousandths of an inch in diameter. The heat then generated, the most intense ever produced up to that time, was about 6,300 degrees Fahrenheit, whereas, if reports are to be credited, Professor Tucker succeeded recently in obtaining a heat of between 6,500 and 6,700 degrees.

The principal aim of the experiment was to determine the commercial value of the extreme heat obtainable from an electric arc, and with this object in view a special furnace was devised which is said to be an improvement over that made use of by Professor Moisson. Artificial diamonds were made by Professor Tucker in much the same manner as those made by Professor Moisson before a New York audience some three years ago, namely, by placing cast-iron chips in a plumbago crucible and covering them with carbon. The whole was then subjected to the full heat of the furnace, after which the crucible and its contents were withdrawn and plunged into icy water, the sudden contraction of the molten iron furnishing the necessary pressure for crystallizing the carbon. The experiment is said to have been very successful in that a diamond larger than any so far made was produced. Aside from this fact, the experiment was interesting as showing the enormous heat which may be produced by the electric furnace, probably the most intense yet ob-

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tained, and which should ultimately be the means of reducing the cost of production of certain substances, such, for example, as calcium carbide, now in demand for commercial purposes."—"The Literary Digest."

THE SMOKE NUISANCE IN PARIS.—Notwithstanding the general impression that Paris is a notably clean city, the growth of the smoke nuisance has forced the municipal authorities to take measures for its regulation by legislation. Before proceeding to do this, however, they appointed, in 1894, a technical commission to investigate the subject. This body has lately completed its labors and has published a report embodying its results and recommendations, an abstract of which is herewith taken from "Engineering Magazine."

The commissioners instituted a series of tests with the view of determining what were the best attainable smoke-preventing devices, and offered prizes to the furnaces demonstrating the best results.

The outcome of this procedure was the entering for competition of no less than 110 smoke-preventing appliances, which may be classified as follows:

(1)	Mechanical stoking and uniform combustion,	16
(2)	Supplementary injection of hot or cold air,	20
(3)	Injection of steam with or without addition of air,	5
(4)	Mingling of flames and combustion of smoke,	7
(5)	Gas producers and gas firing,	7
(6)	Pulverizing the fuel previous to combustion,	2
(7)	Washing of the discharge gases,	16
(8)	Miscellaneous systems,	37

The following information relates to the manner of making the tests:

"The various devices were successively erected under the same boiler * * * and the same fuel was used in all the tests. The fuel was the Anzin briquette, of the ordinary quality, containing an average of 8.17 per cent. of ash and 17.84 per

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cent. of volatile matter. Each device was subjected to two kinds of tests, one with slow firing, and the other with the firing forced to supply the engines fed by the boiler to their full capacity. Each test was made twice, the first time with a stoker selected by the maker of the device, and the second with the stoker employed by the commission, thus eliminating as much as possible the personal equation. * * * The tests included the determination of the quantity of fuel burned per unit of grate area, and the evaporation per unit of area of heating surface and per unit of weight of fuel, as well as the measurement of the relative amount of smoke produced.

"The measurement of the amount of smoke produced by each device was accomplished by an ingenious method, which, while probably hardly entitled to be considered as a method of precision, was still reasonably correct, and doubtless fair to all the devices tested.

"A smoke scale of five degrees of intensity, ranging from complete absence (of smoke) to complete opacity, was decided upon, and the amount produced was recorded upon cylinders revolved by clockwork, by means of a pencil which could be pressed into contact with the paper by hand. The observer, watching the chimney top, pressed the pencil against the paper during any period when smoke was produced, the paper being divided into five portions corresponding to the five grades of smoke."

So much for the method of the tests. The conclusions, which are of general applicability to all cities where the smoke problem is a live question, will be read with interest:

"In the first place, the experiments made before any of the special devices were tried, showed that the ordinary grate is unsuited for smokeless combustion, and that, even with the most careful stoking, the common grate will permit the formation of smoke.

"In the second place, it was clearly demonstrated that smoke prevention and economy do not necessarily go together. The blackest of smoke represents an insignificant amount of fuel, and the tests demonstrated that the devices which produced the least smoke were not the most economical. It should, therefore, al-

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ways be assumed that the prevention of smoke involves expense, proper allowance being made therefor.

"Smoke may always be prevented by using coke, but as this is in many cases unavailable, the only remedy lies in the use of such devices as will produce a minimum of smoke, the true principle being, not the combustion of smoke, but the absence of its production.

"The commission recommended the prohibition of dense black smoke, as the trials showed that many devices would accomplish this result. It was also recommended that those devices which showed the best results during the tests be placed in manufacturing establishments with the view of establishing their durability and effectiveness in regular service, and, above all, that the existing regulations be thoroughly enforced by patient and competent officials."—Franklin Institute.

HIGH TEMPERATURES BY A NEW METHOD.—Goldschmidt, a German investigator, obtains high temperature by the oxidation of aluminum, which he effects by heating a powdered mixture of the metal with some common oxid. The heat obtained, together with the reducing action of the aluminum, enables metals to be smelted by this method. Among other practical applications is the following, quoted from "The Chemical News": "A rivet, such as are employed in bridge making, is embedded in a mixture of oxid of iron, sand and aluminum powder. The whole is plunged in sand contained in a wooden box. On top of the aluminum mixture, which must just emerge from the sand in the box, we place a small lump of a mixture of aluminum powder and an easily-reduced oxid, in which is fixed the end of a short piece of magnesium ribbon. The reaction is started by lighting the free end of the magnesium, and we then immediately place more sand on the top of the mixture, so that as little heat as possible may be lost. If at the end of a few moments we empty out the contents of the box, the rivet will be found to be quite red hot and ready to be forged. Working in an analogous manner, we can weld together steel tubes, and the expense will not be more than twopence. We can even fuse

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together two bars of soft steel." According to the inventor, the temperature obtained under these conditions may be higher than that realized in the electric furnace.—"Literary Digest."

NOTES FROM JAPAN.—On Sunday, June 11, the new dock belonging to the Ishikawajima Iron Works Company, of Tokio, was opened at Uraga. This small harbor, at the entrance of the Tokio Bay, is the place where Commodore Perry touched on his way to Tokio, or Yedo, as it then was called. Uraga is 1½ hours' steaming from Yokohama. It is just outside of the headland at the mouth of Tokio Bay.

The dock, at the entrance of the harbor, is 451 feet in length, from gates to head, breadth at the bottom 54 feet, and depth from the ground level to bottom of dock 32 feet. The blocks are 4 feet high, and the pumps empty the dock in 1½ hours. It will take most of the merchant steamers which frequent Yokohama, with the exception, perhaps, of the French and Trans-Pacific mail boats, the big-blue funnels boats, and the steamers of the Nippon Yusen Kaisha, which ply on the European line. On the day of the opening ceremony the Japanese Australian liner *Futami Maru* was in the dock.

Inside of the dockyard gates there are a laying-down loft, iron heating furnaces, molding shop, iron shipbuilding shop, fitting shop, boiler shop, smithy and stores. There is also a very fine pair of steel sheerlegs, capable of lifting 60 tons, and a club, in which are placed a couple of good billiard tables. The shops are full of powerful first-class machines, mostly from the best of British makers.

At the ceremony the chairman of the company, the well-known banker, Mr. E. Shibuzawa, made a speech, after which communications were read from the Ministers of Trade. At the conclusion of the speeches the guests, about 700 of whom had been conveyed from Yokohama by the steamship *Kobe Maru*, were entertained at a stand-up lunch. After this function there were jugglers and other shows to see. The directors of the company deserve to have their energy repaid by a large business, but the

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drawback, it is thought, will be the distance of the dock from Yokohama.

On the building slips the company have two steam lighters of about 750 tons carrying capacity, for carrying stone for the Osaka Harbor Works. They have hopper bottoms and are of steel. They are about half plated at present. When the ceremony was over the visitors were conveyed back to Yokohama on the *Kobe Maru*, after a very enjoyable day.

This part of Japan is well off for docks now, as, in addition to this one, there are those in Yokosuka, belonging to the Japanese Navy, and the two of the Dock Company at Yokohama. There is also a small mud one at the Ishikawajima works, on the Tokio river. In Kobe there are two slips and a dock in course of construction. At Osaka there is a mud dock. In Kure and Sasebe there are the docks of the Japanese Navy.—"Engineering."

A New Wrinkle in Cooling Machines.—A novel application of thermodynamics to domestic purposes has recently turned up in the shape of an air-cooling apparatus for offices, apartments and habitations. It is a somewhat radical departure from previous methods in that the source of the cooling is not, as generally heretofore, the conversion of mechanical work into the abstraction of heat, either directly or indirectly, but merely depends upon the enormous latent heat of vaporization of water. Water from any convenient source is supplied in a thin film to the copper top of a flat convoluted air flue, and a sharp air blast is directed axially along and over this flue, from a special little blower motor. The forced evaportion chills the air flue vigorously and drops the temperature of the whole air blast from 10 to 25 degrees Fahrenheit, according to the rate of evaporation attained. The net result of this arrangement, the details of which are here only sketched roughly, is to send out into the apartment to be cooled about 10,000 cubic feet of air per hour, cooled to a temperature of about 68 degrees, on an expenditure of about 100 watts. By adjusting the machine the air supplied can be sent out without any added moisture or with such a degree of humidity as may be desired, and the temperature may likewise

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be varied, although as usually adjusted the temperature of the air delivered is controlled automatically within a few degrees range. Obviously such an apparatus is not intended or adapted for cold-storage work or the like, but within the range required for effective house cooling it is enormously more efficient than any machine which depends on the degradation of mechanical energy. The new machine is manufactured under patents to Dr. Louis Bell, and is about to be placed on the market.—"Electrical World."

A Simple Copying Process.—Reference has frequently been made in the pages of the "American Machinist" to methods of copying writings, drawings, etc., by means of the hektograph or gelatine pad and similar preparations, each having its peculiar good features. I have bought or made and have used a number of these devices, but after considerable experiment I have concluded that the most simple and useful for the everyday wants of the business man or the draftsman is one in which gelatine is not used at all, and which is so readily made, kept in condition, and used, as to be a most convenient substitute for at least a large majority of those that have been proposed.

It is prepared by making a putty of whiting and glycerine in the proportion of about four ounces of glycerine to each pound of whiting. Different samples of glycerine require somewhat different proportions, but the point is to give the mass about the consistency of the putty used by glaziers, or possibly a little harder. The prepared mass is placed in a tin tray about $\frac{5}{8}$ inch deep, and carefully smoothed down with a putty knife or similar tool, and finally with a piece of sheet-rubber packing about $\frac{1}{8}$ inch thick, used in the manner of the well-known window cleaner.

The ink used may be almost any of the hektograph inks whose coloring matter is aniline. The following preparation of ink is perhaps as simple as any: Violet aniline, $\frac{1}{2}$ ounce; sugar, $\frac{1}{2}$ dram; boiling water, 2 ounces. Mix thoroughly, and when cold add alcohol and glycerine, of each 1 dram, and dilute carbolic acid, 2 drops. The usual dies sold in the drug stores for coloring fabrics are proper for this purpose, but those for color-

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ing cottons should be chosen rather than those for woolens. The violet aniline makes the strongest ink, although other colors do good work, the proportionate number of copies that may be made being about as follows for the usual colors: Violet, 60 copies; red, 40 copies; green, 30 copies; black, 15 copies.

Much of the success attained is due to good ink, whatever the copying surface used, and, generally, the number of copies which are said to be possible with a certain form of pad is greatly exaggerated. The pad above described is used in the same manner as the gelatine pad, but it has the great advantage that after use every trace of color may be instantly wiped off with a sponge and clean, cold water, leaving the pad ready for use by taking up the surplus moisture with a piece of old newspaper laid flat, smoothed down, and in a minute removed. In some cases, after not being used for a considerable time, the pad may need moistening before use, which may be done with the sponge, and the surplus moisture removed as before.

The economy of this form of pad may be readily appreciated from the fact that whiting costs but about 2 cents per pound and glycerine 4 cents per ounce. A pad of the proper size for a note sheet requires 1¼ to 2 pounds of whiting. When worn away by repeated washings, so as to be too thin for convenient use, the remaining material may be added to the new.—Oscar E. Perrigo, in the "American Machinist."

NAVAL TESTS OF MARCONI WIRELESS TELEGRAPHY.—A special despatch from London of August 5 says: The mimic war between England and Ireland, which began last Saturday, was brought to a close to-day. Sir Compton Domvile, with the British fleet, won, to use the language of the turf, in a canter. With the detached squadron was the *Europa*, which had been fitted in a hasty manner with the Marconi system of wireless telegraphy. In the other portion of the fleet the *Alexandra*, Sir Compton Domvile's flagship, and the cruiser *Juno*, on which was Signor Marconi himself, had been also fitted with the system. The *Juno* was ordered to get in touch as soon as possible with the *Europa* on Monday afternoon. It was a little after 5 o'clock when the instrument in

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Signor Marconi's cabin gave some feeble ticks, and then a message was rapped out that the *Europa* had reached her convoy and was coming to communicate the news to the flagship.

When the *Juno* received this message she was more than forty miles from the *Europa*, and more than seventy from the convoy. Turning about, she proceeded back on her course, and at 7.30 o'clock, when still more than thirty miles from the flagship, she repeated the intelligence she had received from the *Europa*. A second message, sent in the same way, is mentioned by a correspondent, who estimated the distances of the *Alexandra* at the time as thirty miles from the *Juno*, fifty-five miles from the *Europa*, and eighty-eight miles from the convoy. He says, and everyone must agree with him—that it is a veritable triumph for Signor Marconi.—"Electrical World."

THE NEW CHANNEL IN NEW YORK HARBOR.—When it is said that the mud and sand to be removed from the New Nork harbor to make the new channel to the sea, if deposited in the East River, would be sufficient to make the river dry land from shore to shore and from the Battery to Hell Gate, some idea of the size of the colossal undertaking may be obtained. It is estimated that nearly 50,000,000 tons of mud and sand must be removed in order to make the East Channel 40 feet deep and 2,000 feet wide. Congress has appropriated the money, the engineers have drawn the plans, and contracts are being awarded. In order to make the channel it is considered necessary to build new dredges, which will draw up the sand by means of suction pumps. These dredges will be 320 feet long and nearly 48 feet wide, and will have a capacity of 8,000 tons an hour. It will take a year to build the dredges and probably two years more to do the work. The engineer of the Mersey Dock Board recently described the progress of work at the Mersey bar by means of the two huge pump dredges built at Barrow-in-Furness. Whereas at the commencement, in 1890, the shallowest water across the bar was 11 feet at low water of spring tides, there is now a channel of 1,500 feet in width, having practically no less than 27 feet of water in any part on the same condition of tide. The amount of sand

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which had to be removed from the bar itself in order to effect this has been 22½ million tons, and from the bar and main channel 41½ million tons.—"Iron Age."

THE VOLTAIC CELL.—A clear and widespread appreciation of the existing limitations of the voltaic cell as an energy producer would save the community much money every year. Claims are constantly being made by inventors for the superior merits of their new voltaic combinations over engines and dynamos. The law of conservation of energy does not, of course, interfere with any such claim, because the question is entirely one of cost. What is needed is a general recognition of the fact, fully understood by those versed in the science, that a cell which consumes zinc cannot compete commercially with a boiler which consumes coal, so long as zinc requires to be produced by the operation of coal-consuming furnaces.—"Electrical World."

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SHIPS.

UNITED STATES.

Cruisers, 14-19.—Bids for these six protected cruisers, the chief characteristics of which were given in the May issue of the JOURNAL, will be opened on the second day of November. Since the date alluded to was published several changes have been made in the dimensions, so that these now read:

Length on load water line, feet	292
Extreme breadth at load water line, feet	44
Trial displacement, tons	3,200
Mean draught on trial, feet and inches	15-9
Greatest draught full load, feet and inches	16-11
Total bunker capacity, tons, not less than	700
Coal on trial, tons	470
Feed water, trial, tons	40
Speed on trial, knots (at least.)	16½
Horsepower main engines, total	4,500
Horsepower boilers	4,700
Full-load displacement, tons	3,500

General engine data:

Diameter H.P. cylinder, inches	18
Diameter I.P. cylinder, inches	29
Diameter each L.P. cylinder, inches	35½
Stroke, inches	30
Revolutions, full power, per minute	172
Steam pressure at boilers	275
Steam pressure at engine	250
Diameter of crank shaft, inches	9¼
Diameter of crank pins, inches	9¼
Length of crank pins, inches	11
Diameter of axial hole in shaft, inches	5
Diameter of piston valves, inches	11

The sequence of cranks in turning centers is H.P., I.P., forward L.P. and after L.P., while the sequence of the cylinders from forward is, forward L.P., H.P., I.P., after L.P.

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The boilers will be of the straight tube water-tube type and six in number, aggregating a heating surface of 12,600 square feet, and a grate surface of 314 square feet. There will be two smoke pipes 70 feet high from the grate level.

Battleships.—Progress of work on the following battleships is noted from estimates in recent reports, and are mere general indications:

Alabama, 90 per cent. completed. Preliminary contract trial will take place August 28.

Illinois, 80 per cent. completed.

Wisconsin, 70 per cent. completed.

Maine, 10 per cent. completed.

Ohio, 4 per cent. completed.

Missouri, work just begun.

Albany.—Notice has been given that this cruiser will be turned over to the Government before the close of the year. Much interest attaches itself to this vessel, as, while she is a sister ship to the *New Orleans*, which has given so much satisfaction as a fighting machine, she will be a decidedly *improved New Orleans*, having been completed under the inspection of our own naval experts, and embodying many changes from the original design. Lieutenant Harold P. Norton, U. S. N., has been the representative of the Bureau of Steam Engineering in this superintendence and inspection, and we hope to present a complete description by this officer of the vessel, together with the report of her trial, as soon as the latter takes place.

Kearsarge and **Kentucky.**—These battleships, building at Newport News, are rapidly approaching completion. Had it not been for the recent yellow-fever scare in that vicinity it is probable that the trial of the *Kearsarge* would take place in September, though now the prospect is that it will be about November before she will be fully ready for this function. The *Kentucky's* trial should closely follow that of her sister ship.

U. S. S. Dahlgren.—The *Dahlgren*, officially known as torpedo boat No. 10, was successfully launched from the yard of her builders, the Bath Iron Works, Bath, Me., on 29th May. Her contract calls for 30½ knots speed on a displacement of

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about 150 tons. The British 30-knot boats have just twice this displacement, viz: 300 tons, and all the other American 30-knot vessels, with the exception of the *Dahlgren's* sister, *T. A. M. Craven*, also building at Bath, have displacements varying from 250 to 400 tons. The *Dahlgren* is 151 feet long and 16 feet 6 inches beam, with a mean draught, loaded, of 4 feet 8 inches. She is very little larger than the *Foote*, *Rodgers* and *Winslow*, but whereas the latter vessels have machinery capable of indicating but 2,000 horsepower, the *Dahlgren's* have been designed for over 4,200 horsepower. It is also interesting to note that whereas the vessels of the *Foote* class have a trial speed of 24½ knots, the *Dahlgren* will have a speed of 30½ knots, or 6 knots more.

The steel worked into the vessel is all galvanized, and it is 40 per cent. stronger than ordinary ship steel. The machinery of the *Dahlgren* consists of two triple-expansion engines driving twin screws. The cylinders are 17, 25 and 37 inches diameter respectively, the stroke being 21 inches. It will be noticed that the stroke is from 3 to 5 inches longer than the usual torpedo-boat engine, but this long stroke has many advantages, one being that it allows the revolvtions to be kept down. Whereas 400 revolutions and 1,200 feet piston speed is usually adopted for the speed of a torpedo-boat engine, the *Dahlgren's* engine will turn up to about 340 revolvtions when indicating about 4,200 horsepower. There are two Normand water-tube boilers in the vessel, designed to work at 230 pounds pressure. The total grate surface is 118 square feet. The *Dahlgren* will carry 22 tons of coal and 6 tons of feed water. She will be fitted with two deck torpedo guns, discharging 18-inch Whitehead automobile torpedoes, and she will also carry four 1-pounder rapid-fire guns. She was launched with all her machinery on board, and is at present practically completed. Her short, straight smokestacks, rising only just above the awning, with the galley between them, make her appearance quite different from any other American boats. She has two conning towers but no turtleback forward, a long sheer and one small signal spar. She carries two 14-foot cedar boats on deck. She has an electric plant and the usual

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auxiliaries. Her interior arrangements are about the same as all other vessels of this class. The officers and petty officers are berthed aft, and the crew are located forward.

U. S. S. Stringham.—The *Stringham*, the largest and costliest torpedo boat yet built for the United States Navy, was launched from the yards of the Harlan and Hollingsworth Company, Wilmington, Del., on June 10. She will be the pioneer oceangoing vessel of her class, and her guaranteed maintained speed will be 30 knots. The *Stringham's* keel was laid on March 21, 1898. Her length is 225 feet; breadth, 22 feet; mean draught, 6 feet 6 inches, and displacement, 340 tons. This is 70 tons larger than the *Farragut*, twice as great as any other American torpedo boat built or building, and is within 60 tons of the weight of some of the destroyers. Two vertical triple-expansion engines, driving twin screws will develop 7,200 horsepower when forcing the boat at her maximum speed. This power is greater by 1,500 than that of the *Farragut* or any of her class, and equals that of most destroyers. The normal coal supply is 35 tons, but the bunker capacity of the *Stringham* is 120 tons, and with this she will cruise over 1,000 knots. The *Stringham* will carry two 18-inch Whitehead torpedo tubes and seven 6-pounder semi-automatic guns. Her crew will consist of four officers and twenty-eight men.

BRAZIL.

Marechal Floriano.—The cruiser *Marechal Floriano* (3,162 tons), constructed at La Seyne by the Forges et Chantiers de la Méditerranée, for the Brazilian Government, was launched on the 6th of last June.

ENGLAND.

Names Given New Armored Cruisers.—The armored cruiser of 9,800 tons and 23 knots which will be constructed at Portsmouth after the launching of the armored vessel of 15,000 tons and 18,000 horsepower, *London*, will be called the *Kent*.

The order has just been given to Pembroke to put on the stocks *No. 5*, an armored cruiser of the same type, of 23 knots, which will be called the *Essex*.

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The armored cruiser ordered at the Fairfieid Company, of Glasgow, will receive the name of *Bedford*, and that which has been ordered at the London and Glasgow Shipbuilding and Engineering Company, of Glasgow, the name of *Monmouth*.

Barham.—The third-class cruiser *Barham*, of 1,830 tons, made on the 17th of May a forced-draft trial, securing 210 revolutions and 6,150 horsepower, with a full speed of 19 knots. At times the power attained was 6,400 horsepower.

H. M. S. Vengeance, recently launched by Messrs. Vickers, Sons and Maxim, Limited, Barrow-in-Furness, is a first-class battleship laid down on August 23, 1897, and to be completed next spring at a cost of £870,419, according to the navy estimates. She is 390 feet long between perpendiculars, 74 feet beam, and some concessions have been made in her design to insure a draught of only 26 feet when she is in full working order. The displacement then will be 12,950 tons, of which 8,550 tons are due to the hull. She may be said to belong to the *Canopus* class, although, having been ordered a year later, she embodies several changes in detail. Like the five vessels of the type named, her side armor is of 6 inches thickness instead of 9 inches; but, the face being specially hardened, the shot-resisting power will be greater than that nominally corresponding to the thickness. The broadside armor is 14 feet deep, being carried 5 feet below the load-water line. The length is about 196 feet, leaving about 100 feet forward and aft, but this is more nominal than real, for instead of the 'thwartship bulkhead being, as has hitherto been general, at right angles to the line of the ship, the end armor is arranged in the form of a >, the point being towards bow and stern, and as this is from 12 inches to 8 inches thick, thinning towards the bottom, it extends the armor protection. Again, the side armor is carried to the ram as 2-inch nickel-steel plating, which broadens as it extends forward till it reaches from top to bottom, and thus the ram is greatly reinforced. Here it may be said also that the forefoot is greatly cut away, as is also the deadwood aft to improve the circle turning of the ship. Abaft the citadel the side plating is made thicker at the load line for a depth of quite 10 feet. The protective deck

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is 2 inches thick, and, as usual, is curved from the bottom of the side armor to above the water line in the center. This curve enables the engines to be entirely below the deck, obviating the necessity for an armored coaming round the cylinders. There is the usual bunker protection, and coal is carried both under and upon the protective deck, the other levels within the length of the citadel being middle, main, upper and boat decks. The last named, however, does not extend the full width of the ship. At the end of the ship there is a platform below the protective deck.

The barbettes for the pairs of 12-inch guns are immediately within the > at the forward and after end of the citadel. These are 36 feet 8 inches in diameter, of 12-inch Harveyed nickel-steel. There are four casemates on the main deck on each broadside, there being twelve 6-inch quick-firing guns in all, four of them being placed on the upper deck. The bow and stern quick-firing guns have a range to 28 degrees abaft or forward, respectively, and the broadside guns the usual 120 degrees. The casemates are in plan very irregular octagons, the end ones being almost triangular. There are, in addition, eighteen smaller guns, three 12-pounders in the citadel on each broadside on the upper deck, and four on the main deck, two firing forward and two aft. The machine guns are on the bridges and military tops. The masts are very lofty and carry searchlights, which are placed on a platform well raised. There are two navigating bridges, one forward and one aft, and two conning towers, the forward one having 12-inch Harveyed nickel-steel and the after 3-inch nickel-steel. The voice tube and ammunition hoists are armored.

The *Vengeance* is, of course, propelled by twin screws, each driven by an independent set of triple-expansion engines, with three vertical cylinders, of 6,750 indicated horsepower, the aggregate being 13,500. This is attained with the engines making 108 revolutions, and with a steam-boiler pressure of 300 pounds per square inch, reduced to 250 at the engines, and at this point it may be said that the total weight of the machinery, main and auxiliary, including boilers and the water in them, is about 1,290 tons. The high-pressure cylinder is

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30 inches in diameter, the intermediate-pressure 49 inches, and the low-pressure 80 inches, the stroke being 51 inches. The cylinders are separate and independent castings, stayed together, and all the barrels are jacketed. The high-pressure and intermediate-pressure cylinders are each fitted with one valve of the piston type, and the low-pressure cylinder with the ordinary flat valve fitted with equilibrium rings. The valve gear is the double-eccentric ordinary link motion. The straps are separate from the rods, and of forged steel, lined with white metal. Double-cylinder reversing engines are fitted, which in 30 revolutions turn the main engines from full gear ahead to full gear astern. The starting position, it may be added, is amidships.

The bottom frames of the engine are of cast steel, and are bolted together to form one complete bedplate for each set of engines. Bolts, and not studs, are used for securing the main bearing caps. The front columns are forged steel, and the back columns are of cast iron with guides bolted to them.

The pistons are of cast steel of conical form, the piston rods of solid wrought steel 8¼ inches in diameter, with a substantial collar under the piston. Ample surface is provided for the ahead and astern guides. The connecting rods are 8 feet 6 inches long, center to center. The crank and propeller shafts are of forged steel, finished complete at the company's works at Sheffield. The couplings are forged solid with the shaft, except the wrought-iron disconnecting coupling. The total length of the shaft from the main engine to the propellers is about 124 feet. The crank shaft is made in three interchangeable parts, the external diameter being 16½ inches with a 9-inch hole. The length of the main bearings is 9 feet 6 inches. The crank pins are 18 inches in diameter outside and 9½ inches inside, and 20 inches long. The cranks are set at an angle of 120 degrees. The sequence is high pressure, low pressure, and intermediate pressure, the high-pressure cylinder being placed at the forward end and the low-pressure aft. The propeller shafting between the crank shaft and the stern tube is 15½ inches outside and 8¾ inches inside diameter. The stern shaft for the stern tubes is 16½ inches outside, exclusive of the gun-metal casing, and 9 inches inside.

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The shafting beyond the stern tube is 17½ inches outside and 10 inside. The after coupling of the propeller shafting is so arranged that the after length of shafting can be withdrawn in a forward direction without disturbing the stern-tube shaft. The shafting within the tube is effectively cased with gun metal. The thrust block consists of horseshoe collars faced with white metal having a thrust surface of 1,800 square inches for each set of engines. The stern tubes are of gun metal, cast in one length, fitted with lignum vitæ bearings in the usual Admiralty manner. The propellers are four-bladed, of bronze, and 17 feet in diameter, and work inwards. The turning engines, with two cylinders, are capable of turning the main engines completely round in eight minutes with two-thirds the working pressure of the boilers, and when exhausting into the atmosphere. Hand-turning gear is also provided.

The condensers are circular, made of rolled naval-brass plates with gun-metal mountings. One main and one auxiliary condenser is placed in each engine room. The total cooling surface of the two main condensers is 14,500 square feet, and of the auxiliary condensers 2,200 square feet. These latter are used for condensing the steam from the auxiliary engines throughout the ship, and are fitted with a combined circulating and air pump. The condenser tubes are of solid-drawn brass, untinned, ⅝ inch in external diameter and .048 inch thick. The pitch of the tubes is $\frac{31}{32}$ inch. One main air pump is fitted to each main engine, 30 inches in diameter by 19 inches stroke, and is driven by means of levers from the low-pressure cylinder crosshead. These pumps deliver into a hotwell. Two circulating-pump engines are fitted to each engine room. They are of the centrifugal type, having impellers 45 inches in diameter, driven by a compound engine. The duty expected of these pumps is 1,200 tons of water from the bilge per hour with two-thirds the steam pressure, and exhausting into the atmosphere. Either of the two sets in each engine room is large enough for the duty. The circulating sea-suction pipes are 17 inches in diameter and the discharge 19 inches. These engines are placed as high as prac-

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ticable in the engine rooms. The hotwell is of 100 cubic feet capacity and is fitted low down in each engine room. The main air pumps deliver into these hotwells. A pumping engine of the duplex type is fitted to draw from these hotwells and discharge through grease-extractor tanks into the feed tanks. These pumps are also connected to the main condensers. Each grease extractor has over 10,500 square inches effective filtering surface, and the extractors are easily cleaned. Tanks for feed water of about 70 tons capacity are provided in wings and double bottoms. These tanks can be filled by means of injectors at the rate of 50 tons per hour. Means are provided for the admixture of lime with the feed water. The feed pumps (by Messrs. Weir), six in number, are fitted in the boiler rooms; one in each compartment is arranged as a main and one as an auxiliary feed pump. They are of such a capacity that three are sufficient for the full power. The pressure in the feed pipes arranged for is 700 pounds per square inch.

The main steam pipes are of steel, lap-welded with butt-strap over the weld for pipes down to, but not including, 6 inches. Below this they are solid-drawn steel down to 1½ inches in diameter; below this again they are of solid-drawn copper. Reducing valves are fitted in the main steam pipe in each engine room between the main shut-off valve and the regulating valve. Separators are fitted in the engine room, one each side, on the boiler side of the self-closing valve.

There are twenty boilers of the Belleville type, with economizers, and all recent improvements. Each boiler can be used independently of the others, and works at 300 pounds per square inch. The boilers are arranged in three compartments, eight in each of the forward and middle boiler rooms, and four in the after. There is no middle-line bulkhead in the boiler rooms. Fifteen of the boilers have nine elements of large tubes 4½ inches in external diameter, and five boilers consist of eight elements of large tubes 4½ inches in external diameter, each element containing seven pairs of tubes. All the boilers are fitted with economizers, those in the wings of the ship having six elements, and the remainder seven elements, in each case. The economizer elements consist

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of ten pairs of tubes 2¾ inches in external diameter. The heating surface is 21,760 square feet in the main tubes, and 12,010 square feet in the economizers, the total being 33,770 square feet. The boiler tubes are all of British manufacture, as also the material from which they are drawn. The tubes are all solid drawn, finished cold, carefully annealed after manufacture, and subjected to severe tests. Each tube is coated externally with zinc by electro deposition at the Barrow Works.

As to the auxiliary engines in the ship, some brief reference may be made. The distilling machinery, by Messrs. Weir, consists of two evaporators capable of evaporating from sea water 68 tons per 24 hours when worked not compound and 42 tons when worked compound. The two distillers produce 40 tons of fresh aërated water per day for drinking at 15 degrees Fahrenheit above that of the circulating water, with circulating water at not less than 75 degrees Fahrenheit. The electric-light machinery consists of three sets of combined engines and dynamos, the electromotive force being 80 volts for all loads from 10 up to 600 ampères.

There are two double-cylinder, direct-acting steering engines, by Messrs. Caldwell & Co., Glasgow, of sufficient power to move the rudder from hard-a-port to hard-a-starboard, and *vice versa*, through an angle of 70 degrees in 30 seconds, with the vessel proceeding at a speed of 18½ knots and a pressure in the steam-pipes of 200 pounds per square inch. There are four sets of engines and pumps for air compressing, two boat hoists, two refrigerating machines, two coal hoists, five ash hoists, five air-blowing engines, and, for ventilating the ship, there are eight electrically-driven fans, six with 3-foot 6-inch and two with 3-foot discs. These are distributed throughout the ship. There are also two steam fans 7 feet 6 inches in diameter, one in each engine room, and four fans of 8 feet diameter and two of 6 feet diameter for the boiler rooms. Each fan is double breasted.

The ship will have a better appearance than the *Canopus* class, for, in addition to other changes, both funnels are of the same diameter—11 feet. They are 90 feet high from the grates, and are spaced at 23 feet centers. The spacing of masts and funnels

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could be more effective from the point of view of appearance.—"Engineer."

H. M. SS. Hermes and **Highflyer.**—The *Hermes* completed her trials on June 13, and the *Highflyer* ran her official trials between June 20 and 30. Both ships are identical, and the principal dimensions are: Length between perpendiculars, 350 feet; breadth, extreme, 54 feet; displacement, 5,600 tons. There is a cellular bottom extending the full length of the engine and boiler spaces, and before and abaft these the watertight flats of the magazines, etc., continue the double bottom right to the stem and stern. Under the protective deck, the side compartments for the full length of the boiler space are utilized for stowing coal. The hull is subdivided by longitudinal and transverse bulkheads into numerous watertight compartments as usual, the number of watertight doors having been reduced to a minimum, and all being worked from the main deck as well as from below. The stern post, struts and stem are of phosphor-bronze. The stem is of the usual ram form, and the structure behind is especially strong and efficiently connected to the general framework of the vessel with a view to the contingency of ramming. The rudder, also of phosphor-bronze, is of the balanced type and controlled by Harfield's compensating gear below the protective deck. The vessel being intended for foreign service and long cruises at sea, in which the maintenance of a uniform speed becomes essential, she has been completely covered to above the load-water line with teak of a minimum thickness of 3½ inches, and coppered. To secure steadiness of gun platform so necessary in a vessel intended for war purposes, bilge keels extending for about half the vessel's length amidships have been fitted.

The protection of the vessel consists of a curved deck extending from stem to stern, ranging from 3 inches to 1½ inches in thickness, covering the whole of the propelling and steering machinery, boilers, magazines, etc.

The reserve bunkers are on the protective deck over the machinery space, and, whilst affording a water-line belt of coal protection they, being subdivided into watertight compartments, give additional security in the event of damage. An armored

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conning tower of Harveyized steel is placed forward, fitted up with the usual means of navigating the vessel and directing operations while in action, the whole of the connections for which are protected by a steel tube extending to the protective deck. Three searchlights are operated from these bridges, and the vessel throughout is fitted with a complete installation of electric light. Her armament consists of eleven 6-inch and eight 12-pounder quick-firing guns, and a number of smaller machine guns. The guns are all protected by extra-thick shields. Two submerged torpedo tubes are fitted forward, capable of working the latest pattern torpedoes.

The propelling machinery consists of two sets of triple-expansion engines, fitted in two separate engine rooms, each set having four inverted cylinders and four cranks. The high-pressure cylinders are 26 inches in diameter, the intermediate-pressure cylinders, 42 inches in diameter, and each of the four low-pressure cylinders, 48 inches in diameter, all adapted for a stroke of 2 feet 6 inches. The cylinders are all separate and independent castings, each fitted with a cast-iron barrel or liner and steam jacketed. Each of the high-pressure and intermediate-pressure cylinders is fitted with piston valves, and each of the low pressure with flat slide valves, all worked by the usual double-eccentric and link-motion valve gear. The reversing engines are of the all-round type, capable of being reversed, with worm and wheel gear; all the levers being fitted with a slot and adjusting screw to allow of the expansion of steam in the cylinders being altered. The back columns are of cast iron, fitted with separate guide faces, and the front columns are of forged steel, the engines being arranged with the starting platform amidships. The condensers are of brass and placed at the wings. There are two centrifugal pumps of gun metal, each worked by an independent engine, one in each engine room, and arranged with a cross connection, so that either or both condensers can be supplied with cooling water from either pump. The feed, bilge and hotwell engines are all independent and separate from the main engines. Feed-water filters are fitted to prevent any impurities reaching the boilers. The crank, thrust

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MEAN RESULTS OF TRIALS OF H. M. S. *HERMES*.

.....	First 12-hours' 1,000 I.H.P. consumption trial.		Second 12-hours' 1,000-I.H.P. consumption trial.		30-hours' 2,000-I.H.P. coal-consumption trial.		30-hours' 7,500-I.H.P. coal-consumption trial.		10,000-I.H.P. coal-consumption trial.	
Date of trial	May 31, 1899.		June 1, 1899.		May 30, 1899.		June 4, 1899.		June 6, 1899.	
	Stbd.	*Port.*	*Stbd.*	*Port.*	*Stbd.*	*Port.*	*Stbd.*	*Port.*	*Stbd.*	*Port.*
Mean steam in boilers, pounds	239	238	166		270		264		240	
Mean steam at engines, pounds	169	176	124		155		223	222	230	228
Mean cut-off in H.P. cylinder, pr. ct.	20		About 50		About 28		56	56	72	70
Mean vacuum, inches	26.2	26.1	26.7	27	25.4	25.6	25.2	25.9	24.4	24.5
Mean revolutions	84.5	85.3	86.3	86.7	109	108.9	165.3	166.4	181.6	183.9
Mean pressure in cylinders, High, pounds	13.9	10.3	23.9	25.4	34.3	35.1	88.2	91.3	100.0	95.4
Mean pressure in cylinders, Intermediate, pounds	10.5	10.1	8.6	9.4	15.8	14.1	35.6	35.7	40.1	42.1
Mean pressure in cylinders, Low forward, pounds	5.15	7.46	3.8	3.7	6.2	8.5	14.9	16.3	20.6	21.3
Mean pressure in cylinders, Low aft, pounds	4.8	6.04	3.5	3.6	5.5	6.7	14.3	16.7	20 2	21.8
I.H.P. High	89	71	166	177	302	307	1,173	1,220	1,471	1,411
I.H.P. Intermediate	186	182	156	171	361	323	1,237	1,251	1,529	1,627
I.H.P. Low forward	119	174	90	89	186	254	676	743	1,027	1,075
I.H.P. Low aft	112	141	84	85	165	201	648	765	983	1,101
Total I.H.P.	506	568	496	522	1,014	1,085	3,734	3,979	5,010	5,214
Gross total I.H.P.	1,074		1,018		2,099		7,713		10,224	
Mean coal, pounds per I.H.P.	2.61		2.31		2.32*		1.59		1.58	
Speed, knots	10.45		10.4		13.4		18.8		20.5	

* Owing to this high coal consumption, the Admiralty ordered this 30-hours' trial to be repeated.

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and propeller shafting is of forged steel and hollow. The crank-pins are fitted with centrifugal lubricating apparatus. The propellers are of gun metal, each propeller having three adjustable blades.

Steam is supplied by eighteen Belleville water-tube boilers of the latest type fitted with economizers, and adapted for a working pressure of 300 pounds. The boilers are arranged in three boiler rooms, and there are three funnels. Fans and engines are fitted in the stoke holds to insure the necessary supply of air, air-pumping engines being also fitted to deliver air direct into the furnaces and combustion chambers.

MEAN RESULTS OF ADDITIONAL TRIALS OF H. M. S. *HERMES*.

.....	Second 30-hours' 2,000-I.H.P. coal-consumption trial.		Eight-hours' trial at 9,000 I.H.P., with auxiliary-machinery exhaust steam passing to the low-pressure receivers of main engines.	
Date of trial	June 9 and 10, 1899.		June 13, 1899.	
Mean steam in boilers, pounds	196		270	
Mean steam at engines, pounds	126		247	
	Starboard.	*Port.*	*Starboard.*	*Port.*
Mean cut-off in H.P. cylinder, per cent.	35	32.7	56	56
Mean vacuum, inches	26.0	27.0	25.1	25.2
Mean revolutions per minute	111.2	110.6	174.4	176.8
Mean pressure in cylinders, High, pounds	40.2	35.0	105.0	96.6
Mean pressure in cylinders, Intermediate, pounds	16.1	15.9	31.2	31.7
Mean pressure in cylinders, Low forward, pounds	6.86	6.21	23.0	21.8
Mean pressure in cylinders, Low aft, pounds	5.78	5.47	19.5	19.6
I.H.P. High	360	312	1,470	1,374
I.H.P. Intermediate	377	362	1,143	1,176
I.H.P. Low forward	209	189	1,099	1,058
I.H.P. Low aft	176	166	934	949
Gross total I.H.P.	2,151		9,203	
Coal per I.H.P. per hour, pounds	1.78		1.52	
Speed per hour, knots	13.4		20.0	

The vessel is also fitted with the usual auxiliary machinery, viz: a complete distilling plant to supply fresh water to the boilers, and also for drinking purposes; two sets of engines and dynamos for producing the necessary current for electric lighting;

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one double-cylinder engine with the necessary gear for steering purposes; two complete sets of air-compressing engines and pumps, with the air reservoirs, for charging torpedoes; and one refrigerating machine of the cold-air type, with the necessary cold chamber for ship's provisions. The exhaust steam from all of the auxiliary engines in the machinery room, including the steering engines, can be utilized for evaporation or other uses.

Since the first trials, the vessel has made two runs, one at low power, because on the former occasion the conditions at this power did not admit of reliable results being realized; and, as will be seen from the table of results appended, the coal consumption was greatly reduced, being 1.78 pounds. The second supplementary trial was run at 9,000 indicated horsepower, with the exhaust steam from the auxiliary machinery passing into the low-pressure receiver of the propelling engines, an arrangement which gave satisfaction.

The *Highflyer* trials gave even more satisfactory results, the coal consumption being unprecedentedly low on the full-power run, when the boiler pressure was maintained at 292 pounds, and at the engines the mean was 228 pounds. The links were set to cut off at 74 per cent. of the stroke, and the starboard engine, running at 187.6 revolutions, made 5,262 horsepower. The port engine ran 186.5 revolutions. It will be noticed from the table that the power got from the high and intermediate cylinders is almost equal, while the powers of the low-pressure cylinders also closely approximate each other. The variation is practically within the limits of error. This same remark holds good as regards the other trials, the low-pressure cylinders each giving about 66 per cent. of the power indicated in each of the high and intermediate. This arrangement gave most satisfactory results as regards engine balancing, there being practically no vibration. The collective power on this trial was 10,344 horsepower. The speed of this ship was 20.1 knots, which more than meets the expectations of the design. On the 30-hours' trial at continuous sea speed, the steam pressure was 260 pounds, and at the engines it was reduced to 223 pounds. The cut-off was arranged at 56 per cent. of the stroke, and at 169.7 revolutions the starboard

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engine gave 3,828 horsepower, while the port engine recorded 3,816 for 168.1 revolutions. The collective power was thus 7,644

MEAN RESULTS OF TRIALS OF H. M. S. *HIGHFLYER*.

.....	Contractors' 30 hours' 2,000-I.H.P. coal-consumption trial.		Contractors' 30-hours' 7,500-I.H.P. coal-consumption trial.		Contractors' 8 hours' full-power trial at 10,000 I.H.P.	
Date of trial	June 20, 21, '99.		June 22, 23, '99.		June 27, '99.	
Mean steam in boilers, pounds	214		260		292	
Mean steam at engines, pounds	125		223		228	
Mean cut-off in H.P. cyls., pr. ct.	34		56		74	
	Stbd.	*Port.*	*Stbd.*	*Port.*	*Stbd.*	*Port.*
Mean vacuum, inches	26.5	26.0	25.4	26.1	25.6	25.4
Mean revolutions	110.1	110.4	169.7	168.1	187.6	186.5
I.H.P. High	346	320	1,313	1,265	1,610	1,523
I.H.P. Intermediate	341	360	1,087	1,157	1,515	1,513
I.H.P. Low forward	202	191	724	719	1,067	1,040
I.H.P. Low aft	190	185	704	675	1,070	1,006
Gross total I.H.P.	2,135		7,644		10,344	
Coal per I.H.P. per hour, pounds,	1.62		1.49		1.407	
Speed per hour, knots	12.5		19.4		20.1	

indicated, while the speed of the ship was 19.4 knots. The addition, therefore, of 2,700 indicated horse-power to the power, equal to 34 per cent., barely added three-quarters of a mile to the distance run in each hour. This 19½ knots speed was got for an expenditure of 5 tons of coal per hour, which, in view of the displacement, 5,600 tons, is a very satisfactory result, proclaiming not only a high mechanical efficiency, but a beautiful form of ship and great propulsive efficiency. On the low-power trial it was preferred to work the boilers at a high-pressure, reducing it greatly at the engines and cut-off steam in the cylinders at a comparatively late period of the stroke, rather than with a high initial pressure and an early cut-off. The steam pressure was, at the boilers, 214 pounds and at the engines, 125 pounds; this latter enabling the simple auxiliary engines to be worked at a better economy. Sir John Durston, K.C.B., the

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engineer-in-chief, was present at the trials, with Mr. J. Smith, inspector of machinery, Mr. Ellis and Mr. Gregory for the Devonport Dockyard and Mr. Frost for the steam reserve. Mr. Alexander Gracie, the engineer manager at Fairfield, as well as Sir John Durston, is to be congratulated on the results in both ships.—"Engineering."

H. M. S. Ocean.—Her Majesty's first-class battleship *Ocean*, which has been built at Her Majesty's dockyard, Devonport, and engined by Messrs. R. and W. Hawthorn, Leslie & Co., of Newcastle-on-Tyne, commenced her contract trials on the last week of July.

This vessel is the first ship of the *Canopus* type to undergo her steam trials, and is also interesting as being the first battleship in Her Majesty's service which has been tried with Belleville boilers, although, of course, many cruisers have passed through their trials fitted with this type of boiler. She is also of interest as being the first battleship of modern type which has ever been built at Devonport, although two other vessels of this class are now in hand at that dockyard.

The main propelling machinery of the *Ocean* consists of two sets of vertical, three-crank, triple-expansion engines. The diameters of the cylinders are 30 inches, 49 inches, and 80 inches, by 51-inch stroke, and the engines are designed to run at 108 revolutions per minute when indicating full power. All the cylinders of the engines are fitted with separate liners, the high-pressure cylinder being controlled by a piston valve and the intermediate and low-pressure cylinders by double-ported slide valves. All the valves are worked by ordinary double-bar link motion. The bedplates are of cast steel, the back columns being of cast iron and the front columns wrought steel. The condensers, which are of cast gun metal, have a total heating surface of 14,500 feet. All the auxiliary machinery usual in vessels of this class has been fitted.

The boilers, which are twenty in number, are of the Belleville type fitted with economizers, ten of the boilers having nine elements and ten having eight elements. The tubes, which are all of solid-drawn steel, galvanized externally, are 4½ inches outside

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diameter in the generator elements and 2¾ inches diameter in the economizer elements. The total heating surface is 37,715 square feet, of which 24,155 square feet are in the generator elements, and 11,560 square feet in the economizer elements. The total grate area is 1,035 square feet.

The boilers are arranged in three water-tight compartments in two groups of eight and one group of four. The steam pressure is 300 pounds per square inch in the boilers, which is reduced to 250 at the engines by means of Belleville reducing valves.

The contract trials specified are as follows:

1. A preliminary trial at sea.

2. A 30-hours' trial at one-fifth power, *i. e.*, 2,700 indicated horsepower.

3. A 30-hours' trial at 10,250 indicated horsepower.

4. An 8-hours' trial at full power, viz: 13,500 indicated horsepower.

On July 26 the vessel was taken to sea for her preliminary trial, and the machinery was worked gradually up to about 100 revolutions. Everything worked without the slightest difficulty, and on the 27th the vessel proceeded to sea for her 30-hours' trial at one-fifth power. The results of this trial are tabulated below. The trial passed off most satisfactorily, no difficulties of any sort being experienced, the machinery running very smoothly without the slightest signs of heating.

MEAN RESULTS OF 30-HOURS' TRIAL.

		Starboard.	*Port.*
Mean steam in boilers, pounds		210	210
Mean steam at engines, pounds		184	184
Mean vacuum, inches		27.8	27.5
Mean revolutions		66.6	67.0
Mean pressure in cylinders,	High, pounds	41.6	38.2
	Intermediate, pounds	16.2	15.4
	Low, pounds	4.6	4.2
I.H.P.	High	506	466
	Intermediate	527	501
	Low	398	369
Total I.H.P.		1,431	1,336
Gross total I.H.P.		2,767	
Coal per I.H.P., pounds		1.84	
Speed, knots		11.4	

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It will be noticed that the coal consumption is 1.84 pounds per indicated horsepower. It should be mentioned, however, that the modifications which have been made to the auxiliary exhaust system in several recent ships, with successful results in the matter of coal consumption, could not be carried out on board the *Ocean* without delaying the trials, and it was, therefore, decided that these modifications would be made after the ship was taken over.

The Engineer-in-Chief's Department of the Admiralty was represented on the trial by Mr. Ellis, the machinery being in the charge of Mr. D. C. Beadon, on behalf of Messrs. R. and W. Hawthorn, Leslie & Co.

We are able also to give the following synopsis of the 30-hours' 10,250-I.H.P. trial just completed.

		Starboard.	*Port.*
Mean steam in boilers, pounds		259	258
Mean steam at engines, pounds		221	221
Mean vacuum, inches		27	26.2
Mean revolutions		101.9	103.1
Mean pressure in cylinders,	High, pounds	100.	99.3
	Intermediate, pounds	35.9	35.2
	Low, pounds	12.1	10.9
I.H.P	High	1,854	1,862
	Intermediate	1,776	1,763
	Low	1,600	1,459
Total I.H.P		5,230	5,084
Gross total I.H.P		10,314	
Coal, pounds		1.63	
Speed, knots		16.2	

It will be noticed that the coal consumption is 1.63 pounds per indicated horsepower. This figure is interesting, as it compares exactly with the trials of the vessels of the *Majestic* class at 10,000 horsepower. The coal consumption of those vessels varied from 2 pounds to 2¼ pounds per indicated horsepower, so that on the basis of this comparison, which is a perfectly fair one, a very large saving in coal consumption has been made by the introduction of the Belleville boilers, this being especially marked in steaming at relatively high powers.—"Engineering."

FRANCE.

Jeanne d'Arc.—At last this much talked-of triple-screw armored commerce destroyer has left the ways and is afloat.

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The launching took place on June 8th, and was successful. Quite a complete general description of the vessel is given in the JOURNAL, Vol. X, page 864. There seems to be very unusual interest attaching itself to the *Jeanne d'Arc*, both by the English and the French Naval experts, and we quote here part of an article from the "Engineer" on the subject wherein is given some tabular comparative data of the fighting qualities of this vessel with those of the *Terrible* and *Diadem* class of the English Navy.

The further details of the ship and machinery will be given in later issues when they are obtained, and the only dimensions that we will add to the data of the quoted table are that the length of the French cruiser is 447 feet; beam, 63⅔ feet, and draught, 26½ feet.

The comments under the table are also from the "Engineer," and cover several of the points often argued pro and con by the papers of both nations. Of course the results of her trials when finished will be scanned with the deepest interest by all.

.....	*Terrible.*	*Jeanne d'Arc.*	*Diadem.*
Tonnage	14,200	11,270	11,000
Complement	894	626	677
Guns, 1°	two 9.2-inch (B)	two 194 mm. 7.6-inch (C)	nil
Q. F., 2°	twelve 6-inch (D) sixteen 3-inch (12-pounders)	fourteen 5.5-in. (D)	sixteen 6 in. (D) twelve 3-in. (F) (12-pounders)
Q. F. 3°	twelve 3-pounders	sixteen 3-pdrs. eight 1-pdr.	twelve 3-pdrs.
Armor:			
On 1° guns	6-inch (C)	6-inch (C)	.....
On 2° guns	6-inch (*c*)	6 inch (C)	4½-inch (*c d*)
Water line	nil	6-inch (*c*)	nil
Lower deck	nil	3-inch (Z)	nil
Slopes of armor deck in inches, 6 inches equivalent to a protection of	= *a a*	3-inch (*c*)	= *b*
Protection to vitals	= *a a*	= *a a*	= *b*
H.P. (max.)	25,000	28,500 (estimated)	18,000
Speed, (max.), knots	22	23 (estimated)	20.8
Screws	2	3	2
Coal (normal), tons	1,500	1,400 + petroleum	1,000
Bunker capacity, tons	3,000	2,000 + petroleum	2,000

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Now from this it is evident that the armored water-line and extra speed are the *Jeanne d'Arc's pros*, while the lack of 3-inch guns make her armament comparatively inferior. Before, however, proceeding to carry the comparison further, we will give further details of the French cruiser.

The water-line belt is complete. Probably it will, like French belts generally, be completely under water; indeed, by design it is practically that. Above it, however, the lower deck is protected by 3-inch armor of a resisting value equivalent to the coal-bunkers on the *Powerful's* lower deck. Probably there are bunkers behind that might be full; but as the ship will carry only 1,400 tons normally, while the *Powerful* normally stows nearer 3,000 than her nominal 2,000, the *Powerful* has a superior coal protection. Now the 3-inch armor of the *Jeanne d'Arc* is not thick enough to keep out our 6-inch Lyddite shell, consequently, save for hits at a wide angle, is of little more utility than the unarmored side of the *Powerful*, and trusting, as this ship does, to her coal-bunkers, it is not impossible that her water line will prove in practice quite as safe as the *Jeanne d'Arc's*.

The protective deck of the *Powerful* being thicker, it will be noted that her vitals are as safe as those of the *Jeanne d'Arc*. So, so far as the *Jeanne d'Arc* is concerned, are those of the *Diadem;* the 8-inch guns could never penetrate the *Diadem's* decks, except possibly at the muzzle. The weak point in the *Diadem* and the *Powerful*, the ability of 3-inch guns to destroy their water lines, the *Jeanne d'Arc* is not provided to cope with. The entire bow of the *Jeanne d'Arc* is covered with 3-inch armor, some protection to the base of the forward 7.6-inch guns, but again too thin to keep out shell, except at very long range and at an acute angle. She would have to fight at long range to avail herself of it, and then the absolutely unprotected bases of her 6-inch guns would give trouble. The *Powerful* has casements or bunkers under her 6-inch guns, and, being a heavier ship with less armor to carry, she is presumably of stouter construction to withstand shell under the guns.

As originally designed the *Jeanne d'Arc* was to have eight instead of fourteen 5.5-inch guns, and twelve 3.9-inch. These

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twelve would have been carried where the six upper-deck 5.5-inch pieces are, that is to say, eight in caves about the forward group of funnels, and four aft in gun houses of a kind. It was concluded that these 3.9-inch pieces would be of little use, so every other one was knocked out and 5.5-inch guns substituted. This had the additional advantage of simplifying the armament, an important thing, seeing that how to supply the guns has been a tremendous problem even with the simpler armament.

Progress of Work on New Vessels.—The following new ships will be ready for service during 1900. The first named (*Charlemagne*) will probably be commissioned before the beginning of that year:

Battleships *Charlemagne*, *Saint Louis*, *Gaulois* and *Iéna*.

Third-class cruiser *d'Estrées*.

Torpedo gunboats *Dunois* and *Lahire*.

Gunboats *Décidée* and *Zélée*.

Submarine boat *Narval*.

Torpedo boats *225* and *226*.

Seagoing torpedo boats *Lansquenet* and *Cyclone*.

Also about twenty torpedo destroyers and squadron torpedo boats.

Submarine Boats.—"Le Yacht" states that four submarine boats of the *Narval* type are to be built this year at Rochefort, in addition to those building at Havre and Cherbourg. The same paper states that orders have been received at Rochefort to put in hand four torpedo-boat destroyers of the type of the *Fauconneau*, of which the plans are due to M. Normand. They are are to bear the names of *Pertuisane*, *Escopette*, *Flamberge* and *Rapière*. Their length will be 56 meters and their displacement 303 tons. They will each carry one 6.5-centimeter quick-firing gun, six 4.7-centimeter quick-firing guns, and two torpedo tubes. With 38 tons of coal they are expected to run 2,300 miles at 10 knots, or 220 miles at their full speed of 26 knots.

Suffren.—This battleship, of the improved *Iena* class, was successfully launched at Brest last month.

Henri IV.—This battleship is nearing completion at Cherbourg, and has some peculiar features worthy of notice. She

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has usually been considered of the monitor type, save that the main deck proper has only the slight free board of 1.4 meters forward and 80 centimeters aft. There is, however, a superstructure of three-deck height forward of the after turret, the low main deck alone appearing abaft of this turret.

The triple-screw system of propulsion is adopted, and the novelty of two rudders, one between the center screw and each wing screw, is noted. The center screw projects a long way aft from the stern post, and is supported by a heavy steel cylindrical casting, which also carries lugs for stepping the rudders. The wing propellers are 4.5 meters from the center one (center to center).

Dimensions: Displacement, 8,948 tons; length, 108 meters; beam, 22.2 meters; maximum draught aft, 7 meters; horsepower, 11,500.

Triple-expansion engines (vertical) and Niclausse boilers; normal coal capacity, 725 tons; maximum coal capacity, 1,100 tons.

Complement, 26 officers and 438 men.

Jurien de la Gravière was launched at Lorient on the 26th of June in the presence of 10,000 spectators. Her dimensions are: Length, 449 feet; beam, 50 feet; horsepower (designed), 17,400.

She is a triple-screw ship with a normal coal capacity of 600 tons and a maximum of 900 tons, giving a radius of action of 6,150 and 9,300 knots repectively. At 10 knots and at full speed, 880 and 1,330 knots. Her armament will comprise eight 6.4-inch, two 2.5-inch, ten 1.75-inch, and ten 1.5-inch quick-fire guns; also, two underwater torpedo tubes.

GERMANY.

Kaiser Wilhelm der Grosse.—This first-class battleship was successfully launched at Kiel, on June 1, and was the occasion of quite a characteristic christening speech by the German Emperor.

ITALY.

Progress of Work on New Ships.—Orders have been given directing that the armored cruisers *Am. di Saint Bon* and *Emanuele Filiberto*, of 9,800 tons displacement, 13,500 I.H.P. and 18

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knots speed, being built at Venice and Castellamare, shall be completed and equipped by the end of the year, and that the cruiser *Puglia*, of 2,550 tons, 7,000 horsepower and 18 knots, shall be entirely ready at Tarento by the end of 1900. The arsenal of Tarento just commenced the cruiser of the second class, *Basilicata*. The little cruisers, *Agordat* and *Coatit*, of 1,313 tons, 7,500 horsepower and 22 knots, ought to be launched at Castellamare in the present month of June.

Garibaldi.—This new armored cruiser, with an old name, was launched June 29th at Sestri Ponente, at the Ansaldo works. She is larger than the preceding cruiser of the same name, which was sold, being of 7,400 tons against 6,900 tons. Her protection and armament places her in the rank of formidable vessels.

JAPAN.

Sazanami.—On Thursday, July the 20th, the official trial took place of the *Sazanami*, the fourth Japanese torpedo-boat destroyer constructed by Messrs. Yarrow and Co., and as this trial is somewhat exceptional as regards the high speed combined with the low air pressure, we give particulars of it below. The vessel, we may state, was launched on Saturday, July the 8th. Load carried, 35 tons; duration of trial, three hours; coal burnt during the three-hours' trial, 15½ tons. The following figures were obtained on the measured mile:

Hour.	Air.	Mean revolutions.	Time.	Speed.	Mean.	Second mean.	Mean on miles.
	in.		*min. sec.*				*knots.*
11.24	0.82	381.4	2 3	29.268			
					30.850		
11.34	1.06	389.2	1 51	32.432		30.910	
					30.970		
11.43	1.10	390.5	2 2	29.508		31.119	
					31.268		31.183
11.53	1.25	390.6	1 49	33.027		31.298	
					31.328		
12.2	1.20	395.3	2 ·1½	29.629		31.405	
					31.481		
12.11	1.18	390.5	1 48	33.333			
Means,	1⅛	389.6	.....	.....	.....	.....	.....

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The boiler pressure was 230 pounds per square inch, and the vacuum average 24¾ inches of mercury. Mean revolutions for the three hours was 392.09, equivalent to a mean speed during this time of 31.382 knots, and the mean air pressure was 1⅝ inches.

Akebono.—The torpedo-boat destroyer *Akebono* (meaning "Dawn"), built by Messrs. Yarrow for the Japanese Government, is the third of six similar destroyers ordered by Japan, two of which have already been delivered, and three are still to be launched. The *Akebono* has a bunker capacity of fully 100 tons. The vessel is built of galvanized steel alloyed with nickel, the tensile strength being about 40 tons per square inch. This material has been selected on account of its successful adoption in the torpedo-boat destroyer *Sokol*, which was built about four years since by Messrs. Yarrow and Co. for the Russian Government. The *Akebono* is 220 feet in length, 20 feet 6 inches in breadth, and carries an armament of one 12-pounder and five 6-pounder quick-firing guns, besides two 18-inch swivel torpedo tubes. The propelling machinery consists of twin screws actuated by two sets of four-cylinder triple-expansion engines having cylinders 20½ inches, 31 inches, and two of 34 inches diameter with an 18-inch stroke. The engines are designed in conformity with the Yarrow, Schlick and Tweedy system. The machinery is supplied with steam at 230 pounds pressure by four Yarrow straight-tube water-tube boilers. These boilers are the largest hitherto constructed of this type, and they each indicate 1,600 H.P., and weigh 18 tons, including water and all fittings. The *Akebono* was launched on April 24th, and at the official trial on the three-hours' run, with a draught 5 feet forward and 9 feet aft, and a load of 35 tons, attained a mean speed of 31.159 knots, with a pressure of 226 pounds of steam.

RUSSIA.

Gromoboy.—This armored cruiser, of the modified *Rossia* type, was launched May 20th, just one year from the time she was put on the stocks. She has a complete armor belt and the

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hull is sheathed with wood and copper. This is also an addition to the now large fleet of the world's triple-screw warships.

The *Gromoboy* has the following dimensions: Length, 146.3 meters; beam, 21 meters; draught, 7.92 meters; displacement, 12,360 tons.

The original idea was to install 36 Belleville boilers with economizers, but the machinery data will be published when the vessel is nearer completion and details all decided.

The estimated horsepower is 14,500—intended to give at least 20 knots speed.

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MERCHANT STEAMERS.

A New Plant Liner.—Characteristic features of a vessel building for the Plant system by the Wm. Cramp & Sons Co., of Philadelphia, are such as to place her in the front rank of her class. She is intended for coastwise traffic, and is designed to have on a draught of only 18 feet, a cargo capacity of 3,800 tons, and to attain with cargo a speed of 18 knots. This speed is guaranteed on a long-distance loaded trial of a very complete character, much more thorough, indeed, than Government tests, inasmuch as it comprises a requirement of performance on a fixed total quantity of coal.

Dimensions of this new steamer are: Length between perpendiculars, 400 feet; beam, 50 feet; molded depth, 36½ feet; making her one of the largest of her class. The hull will be provided with double bottom, and will be divided into nine compartments by eight watertight bulkheads carried without any openings up to the under side of the main deck. One of these bulkheads divides the boiler room and coal bunkers into two parts, thus reducing the risk of crippling the steam power. Bilge keels of unusual proportions, and a fender for docking, are provided. This vessel will, of course, be classed as an auxiliary cruiser and will enter a trial for classification under the provisions of the postal subsidy act.

Accommodations of a liberal character are provided for 350 first-class and for 100 second-class passengers. These include 100 staterooms, 8 feet deep, opening out on the upper decks. All the first-class accommodations are above the main deck. A handsome saloon to seat 140 persons is on the upper deck, with a ladies' saloon and a smoking room forward, with the purser's office conveniently accessible; also, toilets readily reached, and all under cover. The saloons are lighted and ventilated by a central trunk skylight, 7 feet wide. In the saloon a novel feature

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will be separate tables for parties of four, and in the music room a grand piano will be placed, enabling a singer to face the audience. The upper deck affords a sheltered promenade the full length of the ship of not less than 8 feet width on each quarter, and the awning deck above is 340 feet in length and of not less than 10 feet width, with an extension forward around the foremast, affording to passengers a clear view ahead. On this deck the boats are usually placed, but in this new vessel they will be overhead, and some improvements in arrangements for launching will add to the security of passengers. The engine and boiler-room casings are carried up above this deck to the bridge head, as well as the galley vent, thus freeing passengers from the smells incident to the location of such vents on deck. There are two bridges, one forward and one aft, with two systems of steering, whereby this large vessel can be maneuvered in and out of troublesome channels. Much attention has been directed to the sanitary appliances, which are probably more elaborate than anything heretofore afforded.

Arrangements for rapid handling of cargo comprise five elevators reached by side ports, and a quick-acting winch at forward hatch. Coaling will be effected by a newly-designed apparatus capable of coaling the ship within two hours, a task worthy of note, as she carries five days' supply for full speed of 18 knots, or nine days' supply at reduced speed. Ashes and garbage are dumped directly overboard. A large mail room is provided, with mail doors starboard and port, and with apparatus to deliver and receive mail bags to and from small boats. The vessel will be propelled by twin screws operated by triple-expansion four-cylinder engines. She is to be fitted with two pole masts, carrying leg-of-mutton sails and staysails, and will have two funnels.

Ponce.—The Harlan & Hollingsworth Co. launched, July 22, the new freight and passenger steamer for the New York & Porto Rico Steamship Co., *Ponce*. The *Ponce* is 335 feet over all, 317 feet between perpendiculars, 322 feet on water line, 42 feet beam, and of 19 feet load draught. Other particulars of this vessel are: Deadweight carrying capacity, 3,250 tons; six water-tight

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bulkheads; four winches; two steel masts; deck house of steel; accommodations for seventy-two first-class and twenty second-class passengers; double electric-lighting plant with 232 lights; evaporator with a capacity of 15 tons; five water tanks of 8,000 gallons capacity; engines of direct, tri-compound type with inverted cylinders, 24, 38 and 62 inches diameter and 42 inches stroke; speed, 12 knots; single screw; two steel Scotch boilers, 14 feet 6 inches diameter and 11 feet long, with six furnaces of 48 inches diameter; boiler pressure, 180 pounds; Ellis & Eaves' induced draft; bunker capacity, 350 tons.

Inchkeith.—This screw steamer had its official trial trip on July 8th. The vessel is noteworthy as being the second steamer in which has been fitted a set of Mudd's patent five-crank quadruple-expansion machinery by the Central Marine Engine Works, West Hartlepool. This new departure in marine engine building was taken by the late Mr. Mudd, the first set being fitted in the screw steamer *Inchmona*. The object in the design of these engines and boilers is the attainment of further economy in coal consumption, and the results obtained in the *Inchmona* have fully justified the anticipations of the builders. The *Inchmona* is claimed to be the most economical steamer afloat, the consumption of coal per I.H.P. per hour in that steamer not having averaged more than 1.15 pounds over the whole period during which the vessel has been at sea, viz: since May, 1896. This reduced coal consumption gives larger available capacity for cargo carrying, which means both increase of earnings and decrease of outgoings. The *Inchkeith* is of the following dimensions: Length, 348 feet; breadth, 47 feet; depth, 28 feet 1½ inches, and a deadweight capacity of 6,600 tons on 22 feet 5-inches draught, which is somewhat more than that of the *Inchmona*. The water-ballast capacity is 1,287 tons. The engines are of the same size as those fitted in the *Inchmona*, viz: 17 inches, 24 inches, 34 inches, and two of 42 inches diameter, with a piston stroke of 42 inches. The boilers are of the ordinary cylindrical multitubular type, built for a working pressure of 260 pounds per square inch, and adapted to work with Ellis and Eaves' type of induced draft. In addition to the main feed

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pumps on the engines a pair of Weir's pumps are fitted. The trial was in every way satisfactory, and a speed of over 11½ knots being averaged.—"Engineer's Gazette."

Ortona.—Messrs. Vickers, Sons & Maxim, Limited, launched at Barrow, on July 10, the *Ortona*, a large twin-screw steamer for the Australian mail and passenger service of the Pacific Steam Navigation Company. The steamer is 500 feet long, 55 feet beam and 37 feet molded depth to upper deck, the gross tonnage being 7,600 tons. There are three complete closed-in decks, and accommodation is provided for 130 first, 162 second-class and 300 steerage passengers. The machinery has been designed to give the vessel an average speed at sea when fully laden of 15½ knots.

Montezuma.—Messrs. Alex. Stephen & Sons, Glasgow, launched, on July 11, the twin-screw steamer *Montezuma*, of 490 feet over all and 59 feet beam, with shelter deck fore and aft and upper bridge, built to the order of Messrs. Elder, Dempster & Co., Liverpool.

Wilcannia.—This screw steamer had its official trial trip on July 11th. She is the sixth vessel built by the Sunderland Shipbuilding Company, Limited, to the order of W. Lund, Esq., London. The principal dimensions are: Length, 400 feet; breadth, 48 feet; depth molded, 31 feet 3 inches; and a carrying capacity of 6,000 tons. The vessel has been specially designed for the owner's line, running between London and Australia, and has accommodation for fifty first-class and fifty third-class passengers. The whole of the forehold and fore 'tween decks have been insulated for the carrying of frozen meat. The main engines are by The North Eastern Marine Engineering Company, Limited, Wallsend-on-Tyne, the cylinders being 28 inches, 47 inches, and 78 inches, by 54 inches stroke, with bronze propeller, steam being supplied by four single-ended boilers working at a pressure of 180 pounds, and they are fitted with Howden's patent forced draft. During the trial the whole of the machinery worked with the greatest satisfaction, a mean speed of 13¼ knots being maintained.

Star of Australia.—On Saturday morning, June 24, there was launched from the North Yard of Messrs. Workman, Clark

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& Co., Limited, a large steel screw steamer named the *Star of Australia*, built to the order of Messrs. J. P. Corry & Co., London. The leading dimensions are: Length, 440 feet; breadth molded, 55 feet; depth molded, 33 feet; with a gross tonnage of 7,370 tons. There are five cargo holds, and as this vessel is chiefly intended for the Australian and New Zealand trade, three of these are insulated for carrying frozen meat.

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YACHTS.

Royal Yacht Machinery.—The machinery installation in the royal yacht *Victoria and Albert*, which was recently launched at Pembroke dock yard (see issue of "Review," May 25, 1899, for description of the vessel), is very completely described in "Engineering," of London. Engines and boilers are arranged in four water-tight compartments, the engines being in two, side by side, and the boilers in two, one before the other. The two sets of machinery will develop 11,000 indicated horsepower for eight hours and 7,500 indicated horsepower continuously. The pressure of steam in the boilers will be 300 pounds per square inch, lowered by a reducing valve to 250 pounds at the engines. The engines are of the vertical, four-cylinder, triple-expansion description. The high-pressure cylinder is on the forward side of the intermediate, and these two are between two low-pressure cylinders. The slide valves are of the piston type for the high and intermediate cylinders, and flat valves, with relief rings on the back, are fitted to the low-pressure cylinders. The valves are so set that one-third of the power may be developed in the high-pressure cylinders, one-third in the intermediate and one-third in the combined low-pressure cylinders. The piston and connecting, rods, bearings, etc., are similarly proportioned. In order to make the crank shafts interchangeable the crank pins are all of the same diameter, their lengths being proportioned to give the required surfaces. The cranks are arranged at such angles as will keep the engines free from vibration.

The high-pressure cylinders are 26½ inches, the intermediate 44½ inches and the low-pressure cylinders 53 inches in diameter, with a stroke 3 feet 3 inches. The revolutions for the maximum power will be 140 per minute. The high and intermediate-pressure cylinders are fitted with piston valves, and the low-pressure with flat valves with large relief rings. The valves

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are each worked by double eccentrics and a single solid-bar link. The crank shafts are in two pieces, 14½ inches external and 8¾ inches internal diameter. The crank pins are 15½ inches external and 8½ inches internal diameter, their lengths being 20 inches for the high and intermediate-pressure cylinders, and 13 inches for the low-pressure. The engines are reversed by steam as well as by hand. The reversing engines each have two cylinders 5½ inches in diameter and 6 inches stroke, and make about 130 revolutions in putting the link over from ahead to astern by means of a direct-acting double-threaded screw. To prevent any material amount of racing, each set of main engines is provided with an Aspinall's patent governor, which actuates a throttle valve fitted in the steam pipe close to the regulating valve. A lever is fitted to the back column of the high-pressure cylinder, to which the governor is attached, and this is designed to prevent the engines exceeding their normal revolutions by more than 5 per cent. The steam pipe from the forward boiler room is connected to the starboard engines, and that from the after boilers to the port engines, with a connection in the engine room. Separators with automatic and hand blow-off arrangements are fitted in the after boiler room to these pipes. There are two condensers in each engine room with the requisite connections for working the main engine when either condenser is shut off. This provision is made so that in the event of leakage occurring, the condenser may be disconnected and the defect remedied without stopping the engines. These condensers are placed horizontally, and the water circulates outside the tubes. The tube-cooling surface is 12,000 square feet, or a little less than 1.1 square feet per indicated horsepower. The tubes are ⅝ inches external diameter, secured to the plates by screwed glands and tape packing. The air pumps, 11¼ inches in diameter, are worked directly from each low-pressure piston, and under normal conditions each draws from its own condenser, but means are fitted for supplying each air pump with water to prevent overheating when the corresponding condenser is not in use.

One circulating pump is provided in each engine room, and a

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connection is made through the middle-line bulkhead to allow of either pump supplying all the condensers. The impellers are 45 inches in diameter, and the sea-suction and discharge pipes 16 inches. The usual provision is made for these pumps to draw from the bilge. There are four fire and bilge pumps, each capable of delivering 60 tons of water per hour. These, with the two circulating engines, will, if required, pump about 2,300 tons of water per hour from the bilge. A patent "gravitation" feed-water heater is fitted in each engine room, through which the air pumps deliver into the feed tanks. A vertical auxiliary condenser, with 800 square feet of cooling surface, and a combined circulating and air pump are provided in each engine. A turning engine with two cylinders, 4½ inches in diameter and 5 inches stroke, is fitted in each engine room to move the main engines through one revolution in not more than eight minutes. Provision is also made for turning the engines by hand.

The screw propellers are arranged to work inwards when the vessel is steaming ahead. Each boss is fitted with three adjustable blades. The propellers are of ordinary gun metal, the blades being secured to the boss by bolts of forged bronze. The diameter of the propellers is 13 feet 3 inches. The blades are set at a pitch of 17 feet 6 inches, and have an expanded surface of 12 square feet for each propeller. Duplicate steering engines, by Messrs. Caldwell & Co., Glasgow, are arranged one in each engine room, with shafting, etc., for working them from the bridge. The worms, which are below their wheels, work in an oil bath. At the after end of each engine room, close to the cool chamber, there is a refrigerating machine. Each machine is capable of keeping a chamber of 2,500 cubic feet at a temperature of 15 degrees in the tropics, and of keeping the atmosphere in the chamber dry. There are three sets of electric-light engines with dynamos, each set being of 600 ampères. To assist in ventilating the engine rooms there are four blowing fans, one at each end of each engine room. The main cylinders are clothed on their sides, bottoms and covers with mica. This is covered with polished mahogany secured by burnished brass strips. The flanges are covered with a planished-steel casing fitted in port-

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able sections, so that it may be readily removed. Asbestos cloth is fitted under the attachments of the mahogany and the steel.

The boilers are of the Belleville type, and the safety valves are loaded by springs to 300 pounds per square inch. In the forward compartment there are six boilers, each containing eight generator and seven economizer elements, and three with ten generator and eight economizer elements. In the after compartment there are nine boilers, each with ten generator and eight economizer elements. The generator and economizer tubes are 4 inches and 2¾ inches in diameter respectively. The total heating surface is 26,000 square feet, or about 2.35 feet per indicated horsepower, and the grate surface is 840 square feet, which will give about 13 indicated horsepower per square foot. The feed pumps, which are of the Belleville, vertical, direct-acting description, are in the boiler rooms, there being two main and two auxiliary, each about 11½ inches in diameter and 19¾ inches stroke. In each boiler compartment there is one double-cylinder and one single-cylinder engine for delivering jets of air above the fires and into the combustion chambers to assist in mingling the gases. The boilers are to work under natural-draft conditions, but fans are provided to insure a plentiful supply of air to the stokeholds under all conditions of wind. Four See ash ejectors, with two pumping engines, are provided for discharging the ashes through the sides of the vessel, and there are two ordinary ash tubes and engines for use in harbor.

Nixon's Steam Yacht.—There is now under construction at Lewis Nixon's Crescent Ship Yard, Elizabethport, N. J., a most interesting craft—a steam yacht designed in accordance with the general model of gunboats of the *Annapolis* class, and which is an almost exact duplicate of the *Pathfinder*. This steam yacht is being built on a commission from J. Harvey Ladew, and is designed to replace the yacht *Columbia*, which he sold to the United States Government during the Spanish-American war. This new yacht is, as far as known, the only one in which any regard has been given to the suggestion made since the close of the war that hereafter steam yachts be built with some reference to the possibility of their conversion into auxiliary gunboats. Plans of the

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Ladew yacht were submitted to the Navy Department in order that any suggestions relative to the necessity for stability of construction, were armament to be placed aboard, might be carried out. The same plan was followed as regards interior arrangements, even in the matter of engines.

The Ladew yacht is 200 feet over all, 165 feet on the water line, 33 feet 6 inches beam and 11 feet draught. She will be fitted with triple-expansion engines with cylinders of 18, 27 and 45 inches diameter and 28 inches stroke. Steam will be supplied from two Scotch boilers. It is estimated that her speed will be 14½ knots, and with coal-bunker capacity of 250 tons she will be enabled to steam fully 7,000 miles.

The yacht, which will be brigantine rigged and have a large sail spread, will have double decks, the living quarters being located on the main and berth decks. On the main deck will be a house for the pilot with a bridge on top. The arrangement of the various apartments is in many respects admirable. Each of the five suites will consist of a bed room, sitting room and bath. The main saloon will be 16 by 32 feet; the dining saloon is 18 by 30 feet; a large stateroom 14 by 24 feet extending the full width of the ship, together with pantries, galley and officers' rooms. A handsome library will be a feature of the vessel. Aft there will be eight guests' rooms on the berth deck, two bath rooms and a room with accommodations for four maids. A party of twenty-five can be carried on the yacht with entire comfort. The vessel has an elaborate system of watertight compartments, together with plated decks and watertight hatches.

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ASSOCIATION NOTES.

Another honor to the Engineer-in-Chief, and one which naval engineers unite in deeming most appropriate and deserved, was conferred by the Columbia University of New York, in the form of the Honorary Degree of Master of Science, at the Commencement exercises of that institution, June 7, 1899. Professor F. R. Hutton, head of the Department of Mechanical Engineering of the University, introduced the Admiral in the following characteristic speech, which we are pleased to record in full:

Mr. President: I am to present to you Rear Admiral George W. Melville, Engineer-in-Chief of the United States Navy, who has been named by the Trustees for the Honorary Degree of Master of Science. It is significant that this degree is given today for the first time in the history of the University, and that its award should be to one to whom the honor is so singularly fitting.

I present to you Admiral Melville as a Master of Science, both in that field where knowledge for its own sake is its own exceeding great reward and also in that where the Mechanical Engineer leaves the impress of his thought and creative energy upon concrete achievements in iron and steel.

I bring you, sir, one who has made himself, in the first place, an authority and expert upon Arctic exploration. This knowledge has been acquired in service as an officer, first upon the *Tigress*, in the search for a part of the crew of the *Polaris*, later as an Engineer officer of the *Jeannette*, under Lieutenant De Long, and finally with the relief party which went to rescue Greely with the *Thetis* and the *Bear*. It would be impossible to refrain from a reference to the revelations of personal quality which belong to the experience of these years, and yet only a permitted hand should lift the veil from the tragedies which it conceals. I speak only with bated breadth of the imprisoned *Jeannette*, with her

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frames cracking under the remorseless grip of the ice pack; of the terrible journey across the floes to the launching in the icy sea; of the long exposure to the Arctic gale in open boat, which left its impress on arms and feet, frozen to disablement from exposure; of the lonely landing upon an island of the Lena Delta in Siberia; of the unfaltering prosecution of a search for comrades, when even hardy natives were cowed by the warring elements; of the heartbreaking end of the search when only the dead were found in their last bivouac; of the lonely burial on the shores of the unfriendly sea. These, sir, are memories to thrill under and not to recount lightly.

But I turn rather to the achievements of Admiral Melville in that other field where as a mechanical engineer he has impressed himself upon the engineering of the Navy of our country. Melville is now serving as Engineer-in-Chief of the United States Navy for his third term. When he was appointed in 1888 the only modern vessels in commission were the *Atlanta*, the *Boston* and the *Dolphin*—two cruisers and a dispatch boat. The twelve years of his service have enabled him as Bureau Chief to be responsible for the design and engining of one hundred and twenty ships, aggregating 700,000 horsepower. Beginning with the *San Francisco*, the earliest American-designed vessel of our modern Navy, his sound mechanical judgment, his boldness and his progressiveness have culminated in the *Columbia* and the *Minneapolis*, each triple-screw giants, each holding for a time the world's record for speed.

But, sir, lest I weary with technical detail, I pass to a final reference to that upon which Columbia to-day bases her meed of praise. I refer, sir, to the significance in the war of 1898, which belongs to the preparation and the achievments of the Navy in the Spanish-American conflict. The conception of a floating machine shop, whereby vessels could be outfitted and repaired a thousand miles from a shore basis and a navy yard, and the development of economical distilling ships, whereby a large body of men and vessels on blockade could be supplied with fresh water without the necessity of touching a hostile shore, and the condition of the engineering departments of our

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vessels when the hour of battle had struck, give Admiral Melville's leadership a significance which we are glad to honor. It must not be forgotten, sir, that the achievements of the captains of our fleet are the result, in great part, of the thought, the planning and the capacity of those engineers who gave them their weapons and who operated for them the battle machines with which their work was done.

Sir, I present you Rear Admiral George W. Melville.

At a special meeting of the Council, held August 15, the votes on the proposed change in Article 5 of the By-laws, as noted in the May JOURNAL and also by special cards, were counted, with the result of an almost unanimous assent to the change. One hundred and twenty-three votes were received, of which five only were against the change. The By-laws are herein reprinted as modified in conformity with this vote. See last pages of this issue.

We are in receipt of many inquiries as to the propriety and prospects of retaining the individuality of the American Society of Naval Engineers, now that the Personnel Bill has removed the name of Engineer Corps from the Navy Lists. The inquiries are not unnatural, but imply a misunderstanding of the spirit of the Bill. The Naval Engineer not only exists in the American Navy to-day as distinctly as he ever did, but the whole tenor of the Personnel Bill is to expand the number of Engineers by the addition of all the Line Officers. Eventually this must be the result, as essentially the modern naval officer must be an engineer. There is no diminution of interest in engineering by those who formerly were in the Engineer Corps, and there is no reason for imagining any waning of this interest. There is no profession which is advancing more rapidly, scientifically, than Naval Engineering. Its work approaches that of an exact science, in which generalities are replaced by positive facts and unimpeachable data. Continuous observation and study is the price of the retention of a position even in the rear ranks of the on-

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marching body of the profession, and this Society, with its name and purpose unchanged, will continue to hold a most important place in the Engineering world. If the members will more fully realize this, and lend assistance in furnishing important professional matter for the pages of the JOURNAL, their work will be in line with a right and proper appreciation of the spirit of the Personnel Bill, and also that of the By-laws of the Society.

There is a marked appreciation of the JOURNAL in the Engineering world outside of naval circles, as well as the continued interest within, and a steadily increasing prosperity is encouragement for continuance in the separate and distinct form so long our own, and for the belief that it would be poor policy indeed to in any way unite with other societies of even nearly kindred professions when there is such a growing field of usefulness in the specialties of Naval Engineering.

Article 22 of the By-laws directs that nominations shall be considered at the regular meeting on the first Tuesday in October of each year. While usually most of the nominations are made by members residing in Washington, it is not necessary that this should be so. Any member, wherever stationed, who desires to secure consideration of a particular nomination should submit the same, in conformity with the By-laws, before the October meeting. The nominations should be made separately for President, Secretary-Treasurer, and for three members of Council.

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BY-LAWS OF THE AMERICAN SOCIETY OF NAVAL ENGINEERS.

1. The Association shall be known as the AMERICAN SOCIETY OF NAVAL ENGINEERS.

2. The object of the Society shall be to promote a knowledge of marine engineering and naval architecture by reading, discussing and publishing papers on professional subjects; by bringing together the results of experience acquired by engineers in all parts of the world, which, though valueless when unconnected, tend much to the advancement of engineering when published together in the JOURNAL of the Society; by publishing the results of such experimental and other inquiries as may be deemed essential to the advancement of the science; and historical events in the lives of engineers.

3. The officers of the Society shall be a President, a Secretary-Treasurer, and a Council, all of whom shall be elected annually.

4. The Society shall be composed of Members, Associates and Honorary Members.

5. Officers of the Line and Construction Corps, and ex-officers of the Engineer, Line and Construction Corps of the Navy, and officers and ex-officers of the Revenue Cutter Service shall be eligible as Members.

6. Persons in civil life whose knowledge of engineering is such that they can co-operate with naval engineers in the promotion of professional knowledge, or who are intimately connected with the engineering profession, shall be eligible as Associates.

7. The Secretary of the Navy, the Assistant Secretary of the Navy, the Chief of the Bureau of Steam Engineering of the Navy Department, all ex-Chiefs of the Bureau of Steam Engineering, the prize essayist of each year, and such other persons as the Society may elect, shall be Honorary Members.

8. Members shall be admitted upon application and payment of the annual subscription.

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9. An Associate may be admitted upon application in writing and payment of the annual subscription, provided his application have the recommendation of a member, and receive the approval of a majority of the Council.

10. Associates shall be entitled to all the privileges of Members except voting and holding office.

11. To be eligible as Honorary Member the candidate must receive the unanimous vote of the Council before his name shall be presented to the Society; and the favorable vote of two-thirds of the Members voting shall be necessary for election.

12. The direction and management of the affairs of the Society, and the editing and publishing of the JOURNAL, shall be vested in a Council composed of five members, the President and the Secretary-Treasurer being members *ex officio*. The Council may appoint one of its number Librarian.

13. The President shall exercise the usual duties of that office.

14. The Secretary-Treasurer shall conduct the correspondence of the Society and its financial transactions. He shall submit an annual statement of the receipts and expenditures of the Society, which shall be audited by three other members of the Council.

15. The Council shall have authority to fill vacancies which may occur during the year.

16. Subscriptions, and all matter intended for publication, shall be sent to the Secretary-Treasurer; but no paper shall be read before the Society at the annual meeting, nor anything published in the JOURNAL, without the approval of the Council.

17. In deciding matters pertaining to the Society, none but members shall be entitled to vote; to constitute a quorum for business, nine members must be present.

18. The Society shall meet annually in the City of Washington, and at such other times and places as meetings can be conveniently arranged.

19. The annual subscription shall be five dollars, payable in advance.

20. Copies of the JOURNAL may be sold by the Society at a price which shall be fixed by the Council.

21. Absent members voting on any proposition, must state

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over their signatures whether they are for or against the proposition.

22. On the first Tuesday in October, a meeting of the Society shall be held for the consideration of nominations to offices falling vacant under the rules. Nominations to office must be made in writing, and may be made by any member, whether present at the meeting or not. The consent of the nominee to accept office if elected must be assured. A necessary qualification of all nominees, besides full membership, is residence in or near Washington during the term of office.

23. After the nominations are all made, lists of the candidates for the different offices shall be prepared by the Secretary-Treasurer, and mailed to all Members of the Society. Each voting list must be signed, and must show under the different offices the name of the person voted for. Each voter will enclose his ballot in a sealed envelope, which will be sent to the Secretary-Treasurer previous to the annual meeting. At the annual meeting the envelopes will be opened and the votes counted.

24. Nothing in the preceding section shall preclude the name of any candidate from being put in nomination for more than one office. In case of a tie, the presiding officer shall decide. Voting by proxy is prohibited.

25. In the event of a candidate receiving the greatest number of votes for more than one office, he shall decide which he will accept.

26. Any office falling vacant in the course of the year owing to the death, resignation or removal from Washington or vicinity of the incumbent, shall be filled by vote of the members of the Council remaining.

27. Motions to amend these By-laws, or to make new By-laws, must be in writing, and must lie over at least three months, during which time notice thereof shall be sent to all members; and the assent of two-thirds of the members voting shall be necessary to amend or adopt.

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VOL. XI. NO. 4.

JOURNAL

OF THE

American Society of Naval Engineers.

NOVEMBER, 1899.

PUBLISHED QUARTERLY BY THE SOCIETY.

WASHINGTON, D. C.
R. BERESFORD, PRINTER, 618 F STREET, N. W.
1899.

Entered at the Post office at Washington, D. C., as Second Class Matter.

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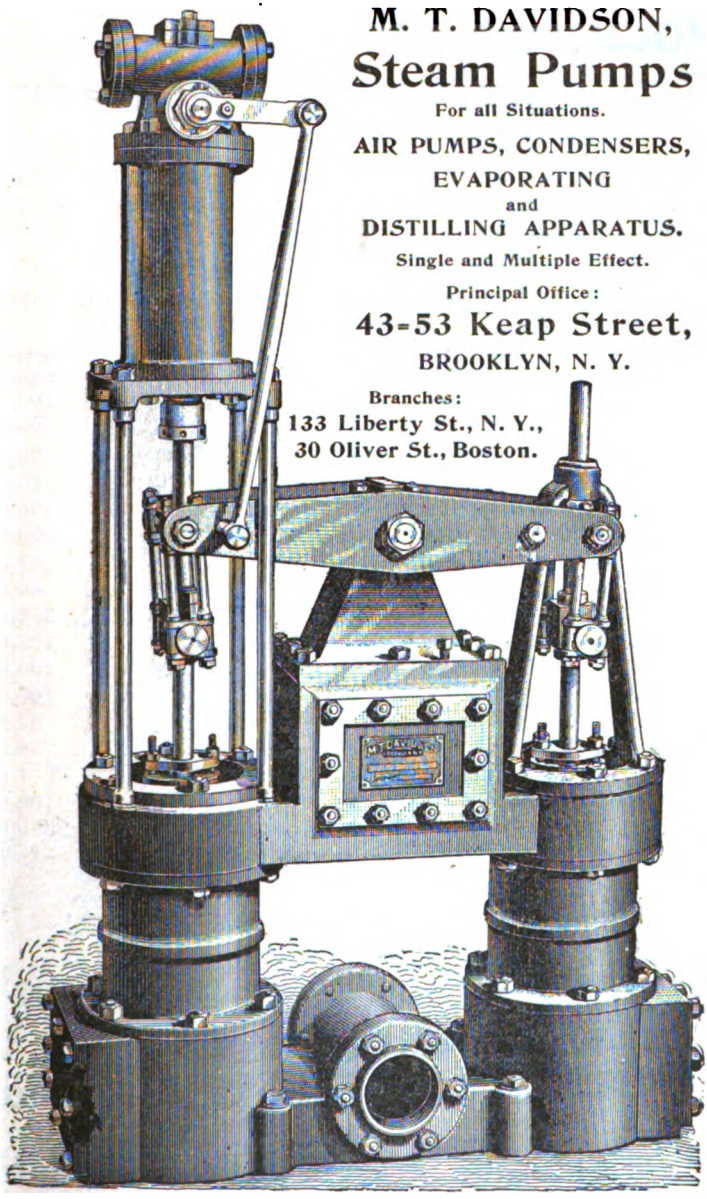

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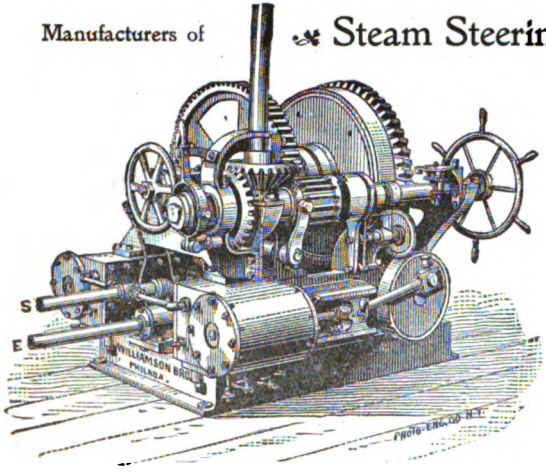

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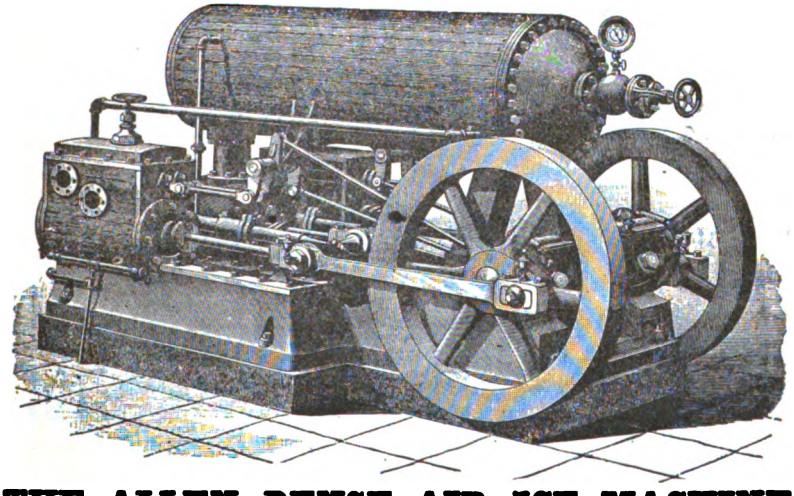

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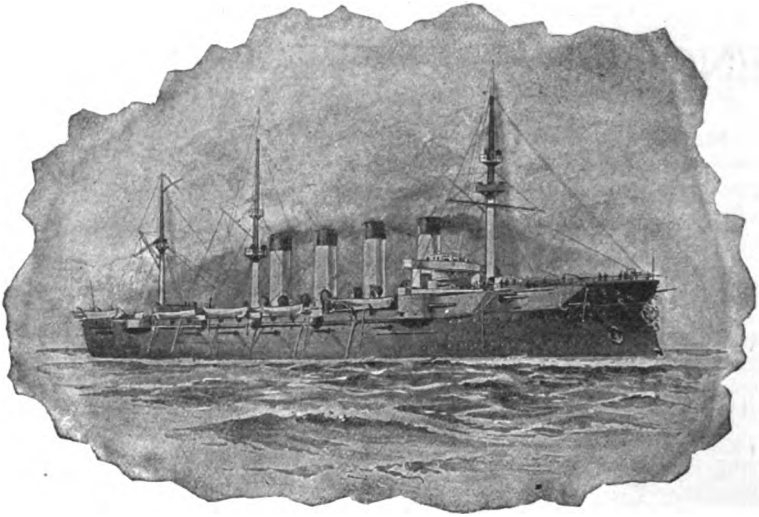

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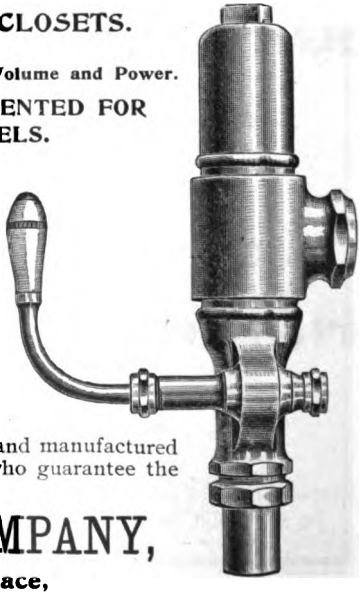

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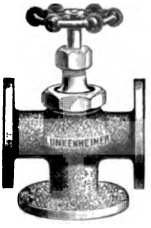

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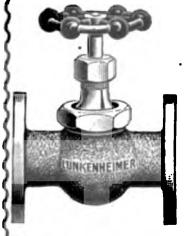

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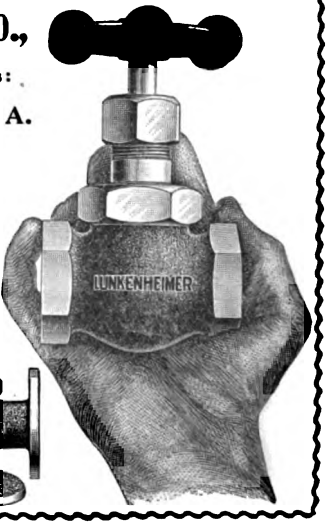

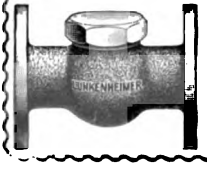

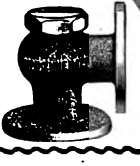

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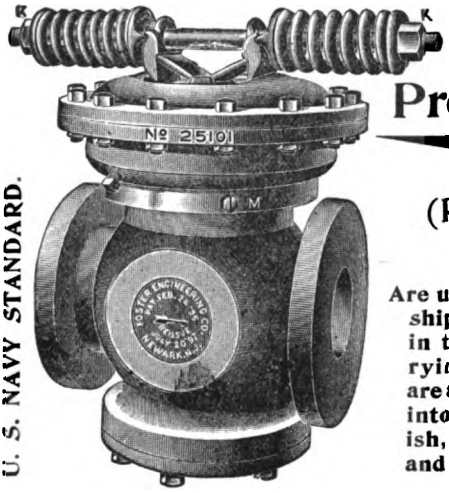

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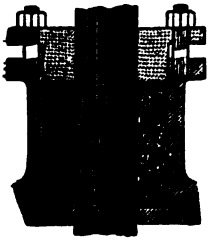

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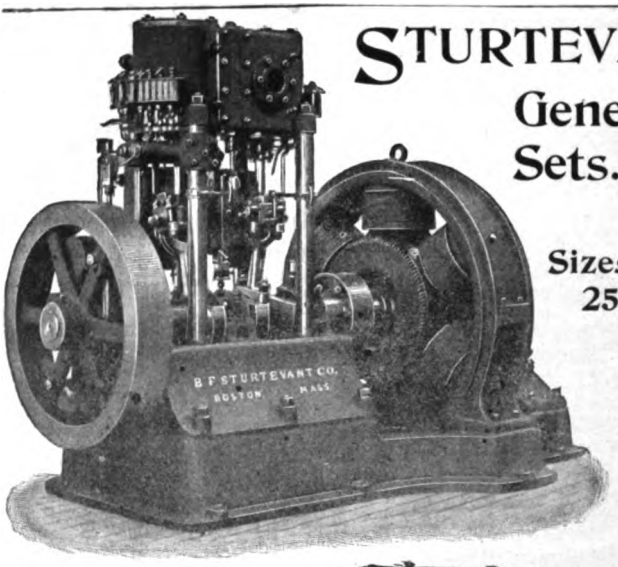

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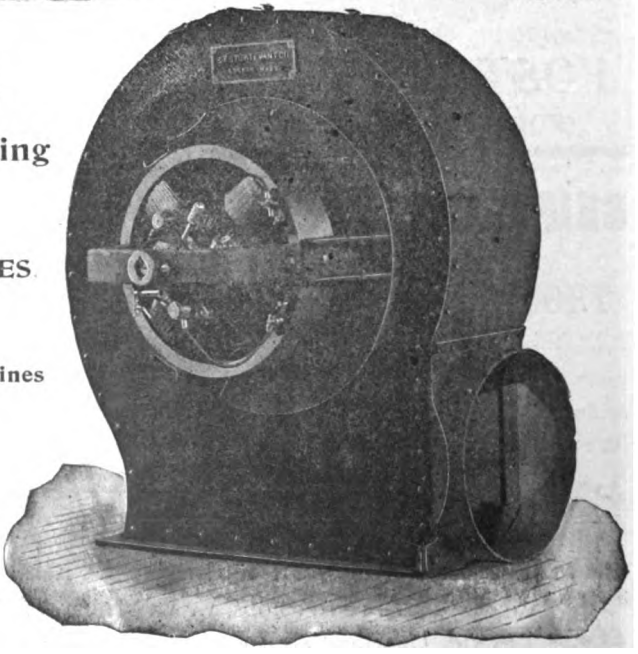

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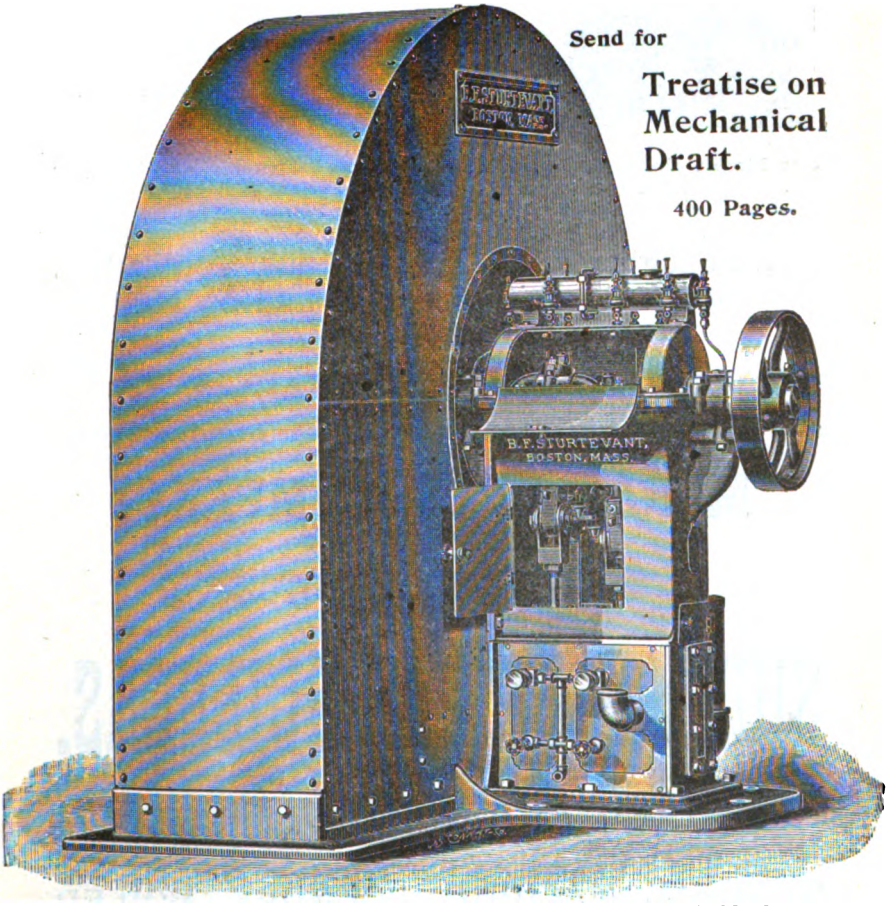

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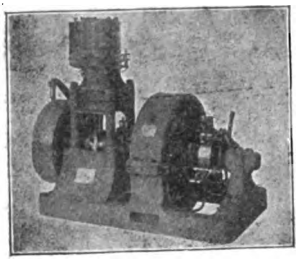

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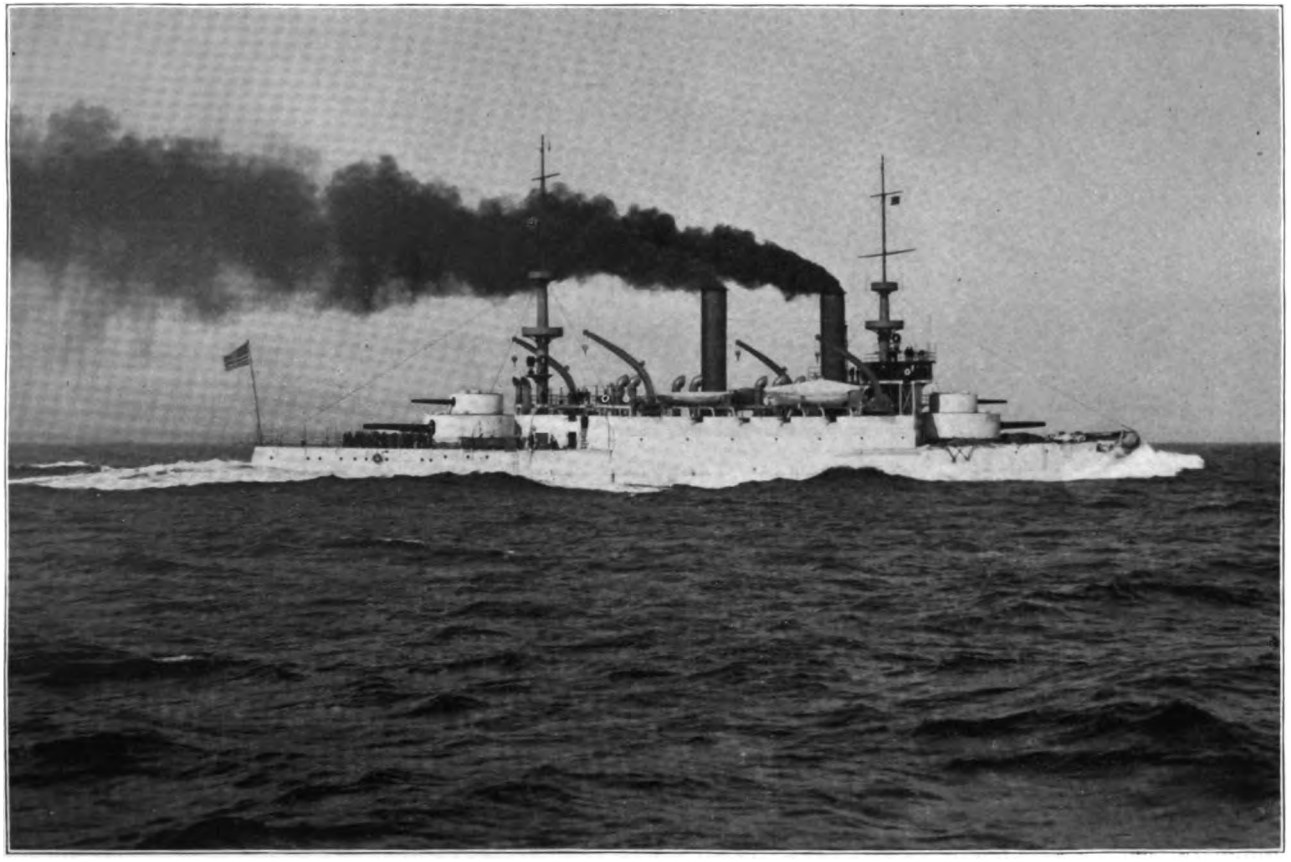

U. S. S. "KEARSARGE." FULL SPEED.

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JOURNAL

OF THE

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VOL. XI. NOVEMBER, 1899. No. 4.

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CONTRACT TRIAL OF THE UNITED STATES SEAGOING BATTLESHIP *KEARSARGE*.

BY LIEUTENANT CLAUDE B. PRICE, U. S. NAVY.

The *Kearsarge* is a twin-screw, armored, seagoing battleship, and was built by the Newport News Shipbuilding and Dry Dock Company, of Newport News, Va. The Navy Department furnished the general plans and specifications for hull and machinery to the contractors and builders, and the latter developed the general designs into exact details, together with the piping systems and location of the auxiliary machinery, submitting their drawings for approval to the bureaus concerned before work was begun. The contract was signed January 2, 1896, the price being $2,250,000, and the time allowed for completion three years. The price stated above does not include the armor (exclusive of that required in the construction of the protective deck), the armor bolts, the ordnance, the ordnance outfit, and certain articles, as anchors and chains, supplied by the Government, but does include the fitting and installation of the above. The speed guarantee was sixteen knots per hour, to be maintained successfully for four consecutive hours, during which

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period the air pressure in the fire rooms was not to exceed an average of one inch of water; the vessel to be weighted to a mean draught of twenty-three feet six inches. No premium for speed in excess of that required by the contract was provided for, but a penalty was inflicted at the rate of $100,000 per knot in case the speed developed should fall below sixteen knots, but if it should fall below fifteen knots, it was optional with the Secretary of the Navy to reject the vessel or accept her at a reduced price. The weight of the machinery was limited to 1,100 tons, which weight included main engines, boilers and appurtenances, distilling apparatus, stores, spare parts, heating apparatus, tools in workshop, and water in boilers, condensers, pumps, pipes and stern tubes, but did not include turret machinery, capstan, windlass, steering gear or winches. The penalty for over weight was $500 per ton up to 5 per cent., beyond which an additional $10,000 was to be attached.

HULL.

Length between perpendiculars, feet	368
on L.W.L., feet and inches	368- 1⅛
over all (including rudder), feet and inches	375- 4½
Beam, extreme, feet and inches	72-2½
at L.W.L., feet and inches	72-2½
Ratio of length to beam	5.20
Depth, from top of main-deck beams at side to bottom of frames at M.P., feet and inches	33- 8
Height of superstructure above main-deck beams to top of hammock berthing on upper deck, feet and inches	12- 0
Draught, normal, forward, feet and inches	23- 7⅝
aft, feet and inches	23- 7⅝
mean, feet and inches	23- 7⅝
Displacement, corresponding to normal draught, tons	11,600
per inch, at L.W.L., tons	47.74
Area of immersed midship section to L.W.L., square feet	1,620
L.W.L. plane, square feet	20,070
Center of gravity of L.W.L. plane, aft of M.P., feet and inches	1- 9
buoyancy above bottom of keel, feet and inches	12- 9⅝
forward of M.P., feet and inches	1- 0½
gravity above bottom of keel, feet and inches	25- 0½
Transverse metacenter above center of buoyancy, feet and inches	16-11¼
Longitudinal metacenter above center of buoyancy, feet and inches	367- 0
Coefficient of fineness on extreme dimensions	.643
of midship section	.957

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Coefficient of fineness of L.W.L.	.757
Cylindrical coefficient	.681
Number of frames	94
watertight compartments	292

The hull is constructed of mild steel of domestic manufacture with frames spaced four feet apart, except when intermediate frames are required, from the stem to frame No. 75; and from this point aft the frames are spaced three feet six inches apart. The ship is divided into two hundred and ninety-two watertight compartments. The double bottom extends from frame No. 28 to frame No. 64 and runs up to the armor shelf. A cofferdam thirty-six inches wide is constructed between the berth and the protective decks, on each side of the vessel, extending from the transverse armor bulkheads to the extremities of the vessel. On the berth deck a cofferdam thirty-six inches above the deck and three feet wide is worked on each side between frames No. 25 and No. 78. The cofferdams are filled with fire-proofed corn-pith cellulose packed to a density of six pounds per cubic foot. All the wood used in the construction of the vessel is fire-proofed, and the use of wood at all is avoided wherever practicable. The upper deck and the main deck, outside the superstructure, are the only ones laid with wood, the others being covered with linoleum.

Main Deck.—On the main deck, inside the superstructure, is located the 5-inch battery in broadside, fitted in stalls formed by splinter bulkheads; on this deck are also located the bakery, galleys, executive officer's and paymaster's offices, junior officers' mess room and pantry. It also forms the principal part of the crew's messing and berthing space, and has much the appearance of the old-time gun deck.

Berth Deck.—On this deck are situated the quarters of the admiral, captain and officers and a berthing space for a part of the crew, and in addition the ice machine and refrigerating rooms, sick bay and dispensary, torpedo rooms, armory, lavatories and coal bunkers above protective deck. On the protective deck are the fresh-water tanks, store rooms, and a small berthing compartment.

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Splinter and Platform Decks and Hold.—Below the protective deck are the machinery spaces, dynamo room, coal bunkers, holds, chain lockers, trimming tanks, store rooms, magazines, shell rooms, blower rooms, central station for interior communications, steering gear, engineers' and ordnance work shops, air compressors and ammunition hoists.

There are thirty-four coal bunkers with a total capacity of 1,591.48 tons at forty-three cubic feet to the ton. They are distributed as follows: Eight on the berth deck with a capacity of 272.02 tons; twelve on the splinter deck with a capacity of 289.63 tons, and fourteen in the hold with a capacity of 1,029.83 tons. They are filled from either the upper or the main deck through portable chutes and trunks fitted between decks. The trunks have shunt doors fitted at the tops where they pass through the bunkers on the berth deck, and vertical doors at the bottom, for passing the coal from the upper to the lower bunkers. Armored shutters are fitted in the trunks where they pass through the protective deck. Trolley rails and buckets are fitted fore and aft in the outboard hold bunkers, with portable sections in the wake of watertight doors, for the transportation of coal. Escape doors are fitted to all bunkers, those on the berth deck open to main deck (circular plates), those on the splinter deck to ammunition passage (swinging doors), and those in the hold to deck of ammunition passage (circular plates). Steam fire-extinguishing pipes are fitted to all bunkers and holds. Over the vertical watertight sliding doors of the hold bunkers are fitted screen doors, in the shape of a hood, designed to take the weight of the coal from the watertight doors, so that they may be easily closed at any time.

There are two ash chutes on each side fitted inside the vessel. The upper ends of the chutes extend above the main deck, where hoppers are formed inside, and so arranged that the fire-main pressure may be used to clear the chute. Trolley ways for carrying the ash bunkers are fitted under the deck beams above, leading from the ash hoists to the chutes.

For convenience in referring to the compartment plans of

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the ship the following list of capacity of each coal bunker is given.

HOLD AND PLATFORM DECK.

Compartment.		Capacity.			
		Cubic feet.		Tons.	
B- 5		2,031		47.23	
B- 6		1,781		41.42	
B- 7		4,675		108.72	
B- 8		4,675		108.72	
B-15		3,598		83.68	
B-16		3,598		83.68	
B-19		3,717		86.44	
B-20		3,717		86.44	
B-27		3,707		86.21	
B-28		3,707		86.21	
B-25		3,214		74.74	
B-26		2,895		67.32	
C- 3		1,484		34.51	
C- 4		1,484		34.51	
Total.....	14		44,283		1,029.83
		SPLINTER DECK.			
B-31		1,584		36.84	
B-32		1,584		36.84	
B-35		1,151		26.77	
B-36		1,151		26.77	
B-53		1,673		38.90	
B-52		1,693		39.37	
B-48		596		13.86	
B-49		596		13.86	
B-59		601		13.98	
B-60		601		13.98	
C-17		612		14.23	
C-18		612		14.23	
Total.....	12		12,454		289.63
		BERTH DECK.			
B-102		1,103		25.65	
B-103		714		16.61	
B-114		1,700		39.53	
B-115		1,700		39.53	
B-123		1,727		40.16	
B-124		1,727		40.16	
B-131		1,510		35.12	
B-132		1,516		35.26	
Total.....	8		11,697		272.02
Total ship.....	34		68,434		1,591.48

Drainage System.—The main drain pipe is of galvanized steel, 14 inches in diameter, and runs from the forward boiler rooms

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along the port side of the center-line bulkhead above the inner bottom to the engine rooms, having branches connecting it with the starboard compartments. It is fitted with screw-down non-return valves in each boiler room, and with screw-down valves in each engine room, all worked from the berth deck. The suction pipes leading from the valves in the boiler rooms do not dip into drainage wells, but have their mouths located as low down as practicable and covered with coarse strainers. The main drain pipe leads to the main circulating pumps, and is also provided with branches and flanges for connections to the principal steam pumps, other than the main feed pumps.

For the auxiliary drainage system manifolds are fitted in the forward and after eight-inch handling rooms, and in convenient locations throughout the machinery space, with suction pipes leading to the double-bottom compartments, trimming tanks and principal lower compartments of the ship, and to sea connections as required. Where these pipes drain water from compartments above the inner bottom a small well is fitted projecting six inches into the inner bottom and covered by a plate strainer. All manifold valves are worked from the manifolds only. A five-inch drain connects the forward and the after manifold, with flanges for the pump connections. In the boiler and engine compartments the suctions are fitted with flanges for a direct connection to the pumps in that compartment, and the crank pits are drained independently of the remainder of the bilge. The compartments above the protective deck are drained by scuppers or portable pumps. The small store rooms below the protective deck are drained by portable pumps, and the coal bunkers below the protective deck by their own vertical sliding doors. The waste water from bath and wash rooms is led by pipes to tanks (two) located in the after part of the engineer's workshop, and is pumped overboard by an ejector.

ARMOR.

The armor consists of a side belt of Harveyized nickel-steel extending 3 feet 6 inches above and 4 feet below the 23½-foot load line. The thickness amidships of the side belt is 16½ inches at

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the top, and 9½ inches at the top of the armor shelf. The maximum thickness of armor at the water line is maintained from the center line of the after barbettes, where the belt begins, to the forward coal-bunker bulkhead, tapering to 10½ inches to the center line of forward barbettes, thence to 4 inches in a distance of 30 feet, which thickness is then maintained to the bow of the vessel. The triangular armor extends from the slopes of the protective deck to the top of the armor belt at the forward and after ends of the machinery spaces, the forward bulkhead being 10 inches and the after bulkhead 12 inches in thickness. Above the side belt there is a casemate 6 inches thick made up of two ½-inch plates and one 5-inch plate; the athwartship bulkheads are 4 inches thick, and are worked from the sides of the vessel to the centers of the barbettes. The thickness of the superstructure armor is 6 inches. The protective deck between armor bulkheads is 2¾ inches thick, and at the extremities on side slopes are fitted plates of armor 4 inches thick. The splinter bulkheads between 5-inch gun stations are each one piece of plate, 80 pounds per square foot.

The barbettes are 15 inches thick at the front and 12½ inches thick at the rear; the 13-inch turrets are 17 inches thick at the front and 15 inches thick at the rear; the 8-inch turrets are 11 inches thick at the front and 9 inches thick at the rear. The conning tower is elliptical in shape, and is 10 inches thick. An armor tube 7 inches thick is fitted between the base of the conning tower and the protective deck, to afford protection to the voice pipes, electric wires, engine telegraphs, steering gear and engine tell-tales.

ARMAMENT.

The main battery consists of four 13-inch breech-loading rifles, 35 calibers, mounted in pairs, in two balanced turrets, on the fore-and-aft center line of the ship, on the main deck; four 8-inch breech-loading rifles, 40 calibers, mounted in pairs, in two turrets superposed on the 13-inch turrets; and fourteen 5-inch rapid-fire breech-loading rifles, 40 calibers, mounted in broadside, on the main deck within the superstructure.

The secondary battery consists of twenty 6-pounder rapid-fire

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guns, eight 1-pounder rapid-fire guns, four of which are automatic, four Colt automatic machine guns, and two 3-inch field guns. There are four tubes for Whitehead torpedoes, two on each side, discharging directly from the berth deck. The turrets are trained by electricity, and the 13-inch guns are elevated and loaded by the same power. The 5-inch guns are worked by hand on central-pivot carriages.

The boats carried are as follows:

One 40-foot steam cutter.
One 33-foot steam cutter.
One 33-foot sailing launch.
Three 30-foot cutters.
Two 30-foot whaleboats.
One 30-foot gig.
One 30-foot barge.
Two 20-foot dinghies.
Two 18-foot balsas.

MAIN ENGINES.

There are two three-cylinder triple-expansion engines of the vertical, inverted, direct-acting type, placed abreast of each other in separate watertight compartments, the H.P. cylinders being forward. The engine framing consists of twelve wrought-steel, cylindrical columns, well trussed and stayed diagonally, fore-and-aft and athwartship; in addition, the H.P. and L.P. cylinders of one engine are secured to the corresponding cylinders of the other, the rod passing through a stuffing box in the center-line bulkhead; also the high and low-pressure cylinders are secured longitudinally to the athwartship bulkheads. The valves are all of the single-ported piston type, there being one for each high-pressure cylinder, two for each intermediate and four for each low-pressure cylinder. The link motion is of the double-bar Stephenson type, and the valve gears of the three cylinders are interchangeable. Independent adjustable cut-off blocks are fitted to each link, with a range from .5 to .7 of stroke. The main valves are provided with balance pistons, the cylinders of which form part of the upper covers of the valve chests. There are no

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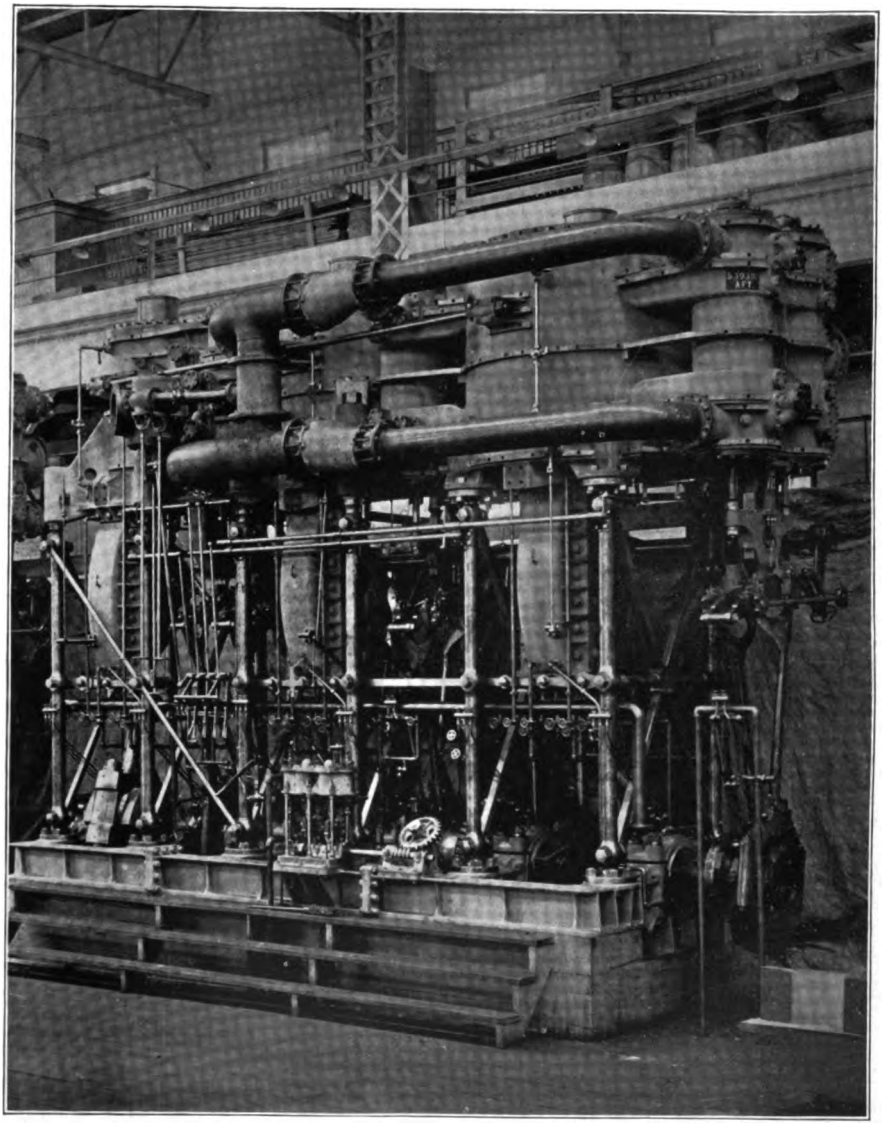

ONE MAIN ENGINE.
(SET UP IN SHOP.)

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starting valves on the cylinders, provision being made for starting the engines by admitting live steam to the receivers. The high-pressure cylinder is steam jacketed around the working linings, and the intermediate and the low-pressure cylinders are steam jacketed around the working linings and at both ends. Each main engine is fitted with a double-disc, balanced, stop and throttle valve, worked by a lever and adjusted by a screw stem and hand wheel from the working platform. The main steam pipes are of copper, and where above 9½ inches in internal diameter are strengthened with steel bands spaced 6 inches between centers. In the starboard engine room there is a 50-gallon distributing oil tank for supplying the oil manifolds of both main engines. This tank is supplied from the main tanks by a Worthington duplex steam pump, and by a hand pump, and can be used as either a pressure or a gravity tank. The main pistons are steel castings, dished, and are each fitted with two packing rings and a follower. The piston rods are of forged nickel-steel, oil tempered and hollow, the outside diameter being 7½ inches and the inside diameter 3½ inches; a screw plug is fitted and riveted over at the upper end. The connecting rods, with their caps and bolts, are of forged nickel-steel, oil tempered; the rods have a 4½-inch axial hole bored through their entire length. The body of the crosshead is forged on the end of the piston rod, and a manganese-bronze slipper, whose sliding faces are fitted with white metal, is bolted to its under side. The crosshead guides are of cast iron, and are made hollow for the circulation of water to keep them cool. At the top they are bolted to lugs cast on the cylinder casings, and at the bottom are bolted to forged-steel cross bars, secured to the engine columns. The backing guides are also of cast iron, and are bolted to flanges provided for that purpose on the go-ahead guides. The eccentrics are of cast iron. Each backing eccentric is securely keyed on the shaft, and each go-ahead eccentric is secured to the corresponding backing one by through bolts in slotted holes. The eccentric straps are of composition, faced with white metal, and the eccentric rods are of forged steel. The I.P. and L.P. valve stems have cast-steel crossheads which take hold of the

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link blocks directly. Each engine bedplate consists of three sections of steel castings.

There is a steam float-lever, reversing gear, with a hydraulic controlling cylinder, which can also be adjusted to work by a hand pump, there being a common piston rod for both steam and water pistons.

The turning engine is a double, inverted, simple, 7 by 5 engine, operating a worm shaft, which in turn operates a second worm shaft and gear made to readily engage in a worm wheel secured on forward end of low-pressure section of crank shaft. The turning-engine shaft is squared at the end and fitted with a ratchet wrench for turning by hand.

ENGINE DATA.

Cylinders, number for each engine	3
H.P., diameter, inches	33½
I.P., diameter, inches	51
L.P., diameter, inches	78
Stroke of pistons, inches	48
Valves, H.P. (one for each cylinder), diameter, inches	19½
I.P. (two for each cylinder), diameter, inches	18
L.P. (four for each cylinder), diameter, inches	18
Balance pistons, H.P., diameter, inches	6
I.P., diameter, inches	7½
L.P., diameter, inches	7½
Valve stems, H.P. (1), diameter, inches	2¾
H.P. (1), diameter through valve, inches	1⅞
I.P. (2), diameter, inches	2¾
I.P. (2), diameter through valve, inches	1⅞
L.P. (4), diameter, inches	2¾
L.P. (4), diameter through valve, inches	1⅞
Main steam pipe (13 inches diameter) area cross section, square inches	132.73
Exhaust pipes to I.P. cylinder, (1) 17 inches H.P. end, 17 inches I.P. end, area of cross section, square inches	226.86
L.P. cylinder, (4) 15 inches I.P. end, (8) 11 inches	706.50
L.P. end, area of cross section, square inches	759.88
condenser, (2) 19 inches diameter, area of combined cross section, square inches	566.77
Volume swept by H.P. piston (mean), per stoke, cubic feet	23.84
I.P. piston (mean), per stroke, cubic feet	56.09
L.P. piston (mean), per stroke, cubic feet	132.04
Net area of I.P. to H.P. piston	2.34
L.P. to I.P. piston	2.36

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Net area of L.P. to H.P. piston	5.53
Clearances of H.P. cylinders, per cent.....top, 18.9; bottom,	22.8
I.P. cylinders, per cent.....top, 18.9; bottom,	24.7
L.P. cylinders, per cent.....top, 17.5; bottom,	22.9
Piston rods, diameter, inches	7½
length from piston to crosshead, feet and inches	6– 6⅛
Connecting rods, length from center to center, feet	8
diameter of upper end, inches	7⅜
diameter of lower end, inches	8¼
crosshead bolts (2), diameter, inches	4¼
crank-pin bolts (2), diameter, inches	4¼
Crossheads, surface (ahead), square inches	459
(backing), square inches	357
pins, diameter, inches	9¾
length, inches	14
Reversing gear, steam cylinder, diameter, inches	15
controlling cylinder, diameter, inches	7½
Crank shafts, diameter, inches	14¾
axial hole, inches	7½
coupling discs, diameter, inches	29
thickness, inches	3½
bolts in one flange (6), diameter, inches	3½
journals, diameter, inches	14¾
length, inches	16½
length of each section, feet and inches	8–10
Crank pins, diameter, inches	14¾
length, inches	17
axial hole, inches	7½
Crank webs, width, inches	16¼
thickness, inches	10
Thrust shaft, diameter, inches	14
diameter of coupling disc, inches	29
axial hole, inches	9
collars, number each shaft	11
diameter, inches	21½
thickness, inches	2
distance between, inches	3½
surface, total for both engines, square inches	4,600.64
length, feet and inches	15– 5¼
Line shafts, diameter, inches	14
axial hole, inches	9
diameter of coupling discs, inches	29
length, feet and inches	31–10⅛
Propeller shafts, diameter, inches	14¾
axial hole, inches	9¾
Propeller shafts, outboard, length, feet and inches	26– 5½

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Propeller shafts, outboard, coupling, diameter, inches	21
length, feet and inches	4– 8½
inboard, length, feet and inches	31–10
Stern bracket bearing, length, inches	48½
diameter, inches	16 13/16
tube bearing, length, forward, inches	40¾
aft, inches	42

Shafting and Bearings.—The crank shafts are of forged steel, and for each engine are made in three interchangeable and reversible sections, the cranks being 120 degrees apart, and for the ahead motion follow in the order H.P., I.P. and L.P. There is a 7½-inch axial hole through crank shaft and pin. The line, thrust and propeller shafting is hollow and of forged nickel-steel. The propeller shafts are fitted with a composition casing from inboard of the stern-tube stuffing box to the propeller hub. The propeller shaft is in two sections connected by an outboard sleeve coupling fitted near the after end of the stern tube, and protected by a water-tight covering. The thrust bearings are of the horseshoe pattern; the pedestals are of cast iron, the ends and side walls forming an oil trough; at each end there is a bearing, lined with white metal, for taking the weight of the shaft. The horseshoes are eleven in number and are of cast steel, faced with white metal, and fitted with oil cups and holes for the distribution of oil to the bearings. At each end of the bearing there is a divided stuffing box and gland to prevent the escape of oil. The pedestal is bolted to a cast-iron sole plate, fitted with wrought-iron wedges at each end of the pedestal for adjusting the bearing fore and aft.

Main Condensers.—There are two main condensers, one for each engine, the shells are of wrought-steel plate, with an angle-iron riveted around each end forming a flange for securing the water chests. The water chests and tube sheets are of composition. The circulating water passes through the tubes. Baffle, circulating and tube-supporting plates are fitted. There are by-pass valves in the after water chests to allow the water from the circulating pumps to pass directly overboard.

Diameter of shell (inside), feet and inches	5– 8½
Thickness of shell, inch	5/16

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Length over heads, feet and inches	13- 4
Tubes, diameter (outside), inch	$\frac{5}{8}$
length between tube sheets, feet and inches	11- 6
thickness, No. 18 B.W.G., inch	.049
number in each condenser	3,749
Cooling surface, each condenser, square feet	7,050
Total cooling surface, square feet	14,100
Ratio of total cooling to total heating surface	1 to 1.56

Main Air Pumps.—For each main engine there is a Worthington twin-cylinder, vertical, single-acting air pump. The steam cylinders are placed directly over the pump cylinders, the pump rods and piston rods forming a continuous length. The pumps are connected by means of a beam, which is pivoted at its center, and from which beam the valve motion is actuated. The beam receives its motion through links swinging from crossheads on the pump and piston rods. The pump valves are each made of three flat discs of rolled manganese-bronze.

Diameter of steam cylinders (2), inches	12
pump cylinders (2), inches	25
Stroke, inches	18
Diameter of piston rods, inches	$2\frac{7}{16}$
pump rods, inches	$2\frac{3}{4}$
Diameter of pump valves, inches	3, 4, $4\frac{1}{8}$
Ratio of volume swept by L.P. piston, net area, per stroke, to that of the two air-pump buckets, per stroke	13

Main Circulating Pumps.—For each condenser there is a centrifugal, double-inlet circulating pump, which is arranged to draw from the sea, bilge and main drain pipe, and to discharge either into the condenser or directly overboard. The sea and bilge injection valves are fitted with a self-locking arrangement so that both cannot be operated at the same time. One of these pumps was tested under conditions assimilated to that of drawing water from the bilge and discharging directly overboard, the length and size of the piping and the head at discharge being the same as would occur in actual service. The velocity at discharge was measured by a small propeller, and the results were well over their rated capacity of 10,000 gallons per minute.

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Diameter of steam cylinders, inches	11
Stroke, inches	8
Diameter of pump runner, inches	42
Width of runner, inches	8¾
Diameter of inlet and of outlet nozzle, inches	15½

Auxiliary Condensers.—There is in each engine room an auxiliary condenser connected with the auxiliary exhaust pipes. The heads and shell are of composition and the tube sheets of rolled brass. Each has a Worthington horizontal, duplex, combined air and circulating pump, the steam cylinders being between the water cylinders, and all the pistons being on one rod. The tubes are arranged and packed as in the main condensers.

Cooling surface, one condenser, square feet	801
Diameter of steam cylinders, inches	7½
circulating-pump cylinders, inches	8½
air-pump cylinders, inches	8½
Stroke, common, inches	10

Feed-Water Heaters.—In each engine room there is a feed-water heater which is similar in construction to a condenser. The auxiliary exhaust pipe has a by-pass valve, so that the exhaust steam may be passed around the tubes of the heater and thence to the condenser. The heaters are located between the feed pumps and the feed main, and the valves are so arranged that the feed water can pass directly to the feed main without passing through the heaters. The heating surface is 496.5 square feet for each heater. The tubes are 1 inch in outside diameter, No. 13 B.W.G. in thickness, and are expanded into the tube sheet. The tubes are tinned inside and out.

Screw Propellers.—The propellers are rights and lefts, of manganese-bronze, each with three adjustable blades bent back 30 inches. They are true screws, with the pitch adjustable from 16 to 18 feet. Each boss is secured to the shaft by two feather keys and a wrought-steel nut screwed on and locked in place. The end of the hub is covered with a composition cap. The blades and boss are tinned, and the outboard sections of propeller shafts are protected by a covering of insulated copper wire, wound tightly around the shaft casings.

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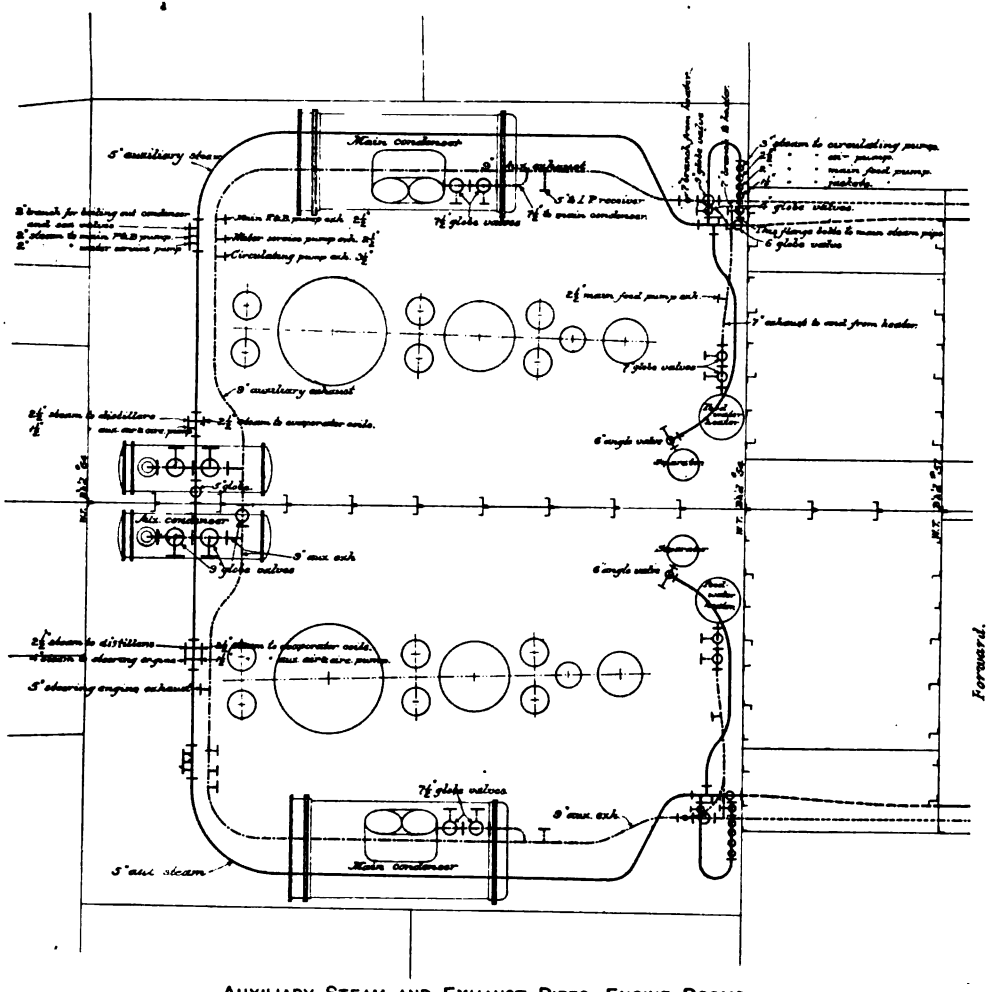

AUXILIARY STEAM AND EXHAUST PIPES, ENGINE ROOMS.

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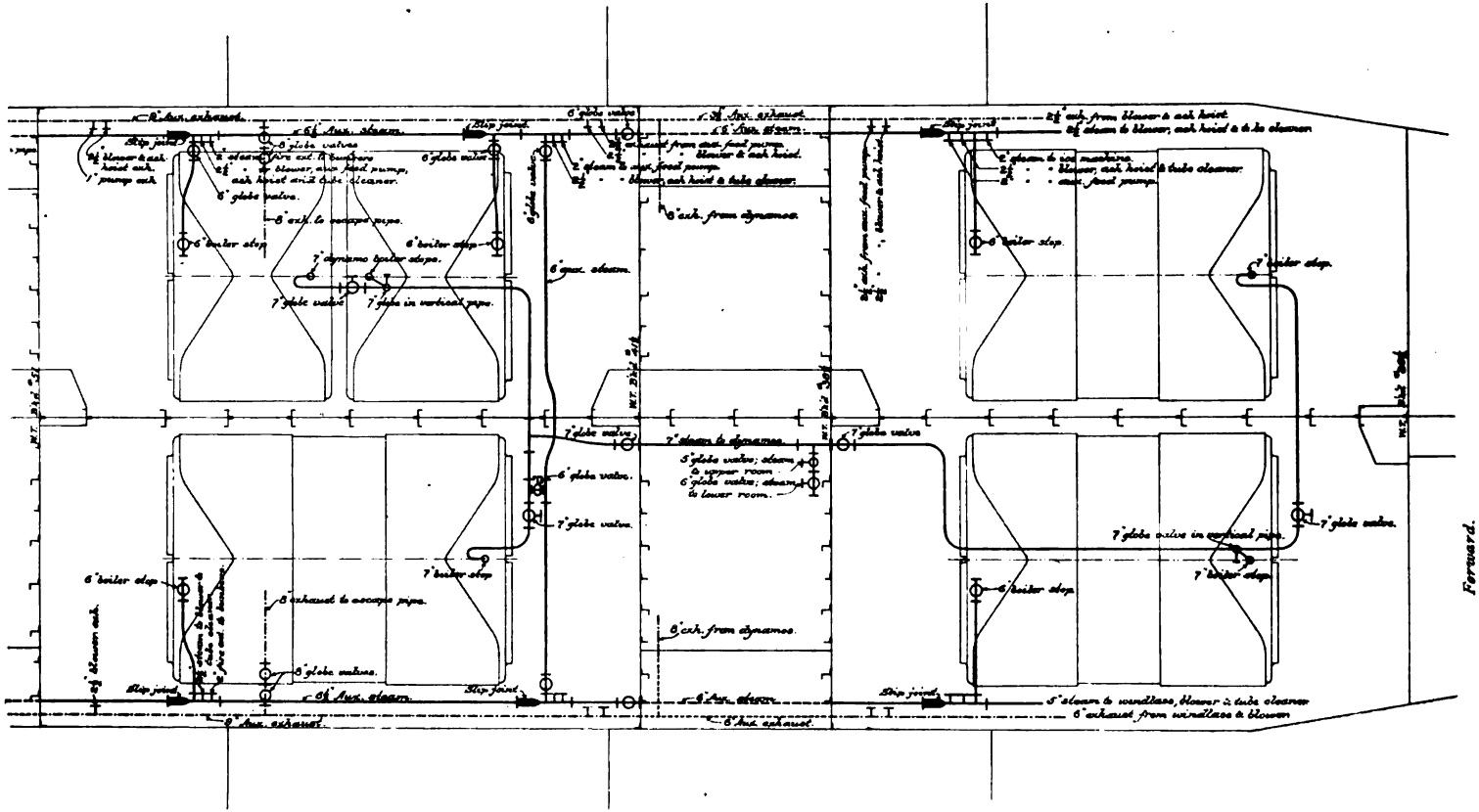

AUXILIARY STEAM AND EXHAUST PIPES, FIRE ROOMS.

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Number of blades	3
Diameter, feet and inches	16– 9
of hub, feet and inches	4– 4½
Length of hub, feet and inches	3– 1
Pitch as set, feet and inches	17– 3
Greatest width of blade, feet	5
Helicoidal area of each screw, square feet	84.2
Projected area, square feet	69.2
Disc area, square feet	220.35
Pitch ÷ diameter	1.03

BOILERS.

There are three double-ended and two single-ended steel boilers of the horizontal, return, fire-tube type, all 15 feet 8 inches in diameter. Each double-ended boiler has eight and each single-ended boiler four corrugated furnaces. The shell of each double-ended boiler is made up of three courses of three plates each; the longitudinal joints are treble riveted with double butt straps; the circumferential joints are lapped and treble riveted, and the heads lapped and double riveted. The shell of each single-ended boiler is in one course of four plates, double butt strapped and treble riveted, the joints with the head lapped and double riveted. The joints in the furnaces and combustion chambers are single riveted. The heads of all boilers are curved at the top to a radius of 3 feet 7 inches.

The furnaces are fitted with the ordinary cast-iron fixed grate bars. Each double-ended boiler has four 4½-inch spring safety valves, two in one case, and each single-ended boiler two 4½-inch safety valves in one case. The internal feed pipes are fitted with suction branches to the bottom of the boilers, the combined feed and "circulated" water being discharged near the water level through down-pointing branches. The auxiliary feed pumps may also be used to circulate the water. The tubes in all boilers are of knobbled charcoal iron.

The boilers are placed fore and aft in four water-tight compartments, the two single-ended boilers occupying the after port compartment. The passageways are outboard and alongside of the boilers, with passage amidships connecting the port engine room with the port after fire room. There are two athwartship fire

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rooms in each boiler compartment, and eight fire rooms in all. There are two circular smoke pipes. The working pressure is 180 pounds per square inch.

DOUBLE-ENDED BOILERS.

Length, feet	one of 21 and two of 19
Diameter, outside of all, feet and inches	15- 8
Thickness of shell and heads at top, inches	$1\frac{7}{16}$
heads, bottom, inch	$\frac{3}{4}$
tube sheets, inch	front $\frac{7}{8}$, back $\frac{3}{4}$
furnaces, inch	$\frac{9}{16}$
Combustion chambers, number in each boiler	4
thickness of plates, inch	$\frac{9}{16}$
depth at top, inches	$27\frac{1}{2}$
Furnaces, greatest internal diameter, feet and inches	3- $5\frac{7}{8}$
least internal diameter, feet and inches	3- 3
length of grate, feet and inches	6- 7
number in each boiler (corrugated)	8
Tubes, outside diameter, inches	$2\frac{1}{4}$
length between tube sheets, 21-foot boiler, feet and inches	7- $7\frac{3}{8}$
19-foot boilers, feet and inches	6- $7\frac{3}{8}$
number of ordinary	816
number of stay	332
spaced vertically, inches	$3\frac{1}{4}$
horizontally, inches	$3\frac{1}{2}$
thickness of ordinary, B.W.G. No. 10, inch	.132
stay, B.W.G. No. 6, inch	.203
Diameter of rivets in shell sheets, inches	$1\frac{5}{16}$
screw stays, inches	$1\frac{1}{2}$
Number and diameter of through upper braces, inches	10 of $2\frac{3}{4}$
lower braces, inches	2 of $1\frac{3}{4}$
braces from head to back tube sheets, inches	15 of $1\frac{3}{4}$
Heating surface, tube, square feet, 19-foot boiler, 4,473; 21-foot boiler,	5,150
plate, square feet, 19-foot boiler, 847; 21-foot boiler,	901
total, square feet, 19-foot boiler, 5,320; 21-foot boiler,	6,051
Grate surface, square feet	171.2
Area through tubes, square feet	23.8
over bridge walls, square feet	24.5
Volume of furnaces and combustion chambers above grates, 21-foot boiler, cubic feet	725
Volume of furnaces and combustion chambers above grates, 19-foot boiler, cubic feet	699
Steam room, 4 inches above highest heating surface, 21-ft. boiler, cu. ft.	808.5
19-ft. boiler, cu. ft.,	716

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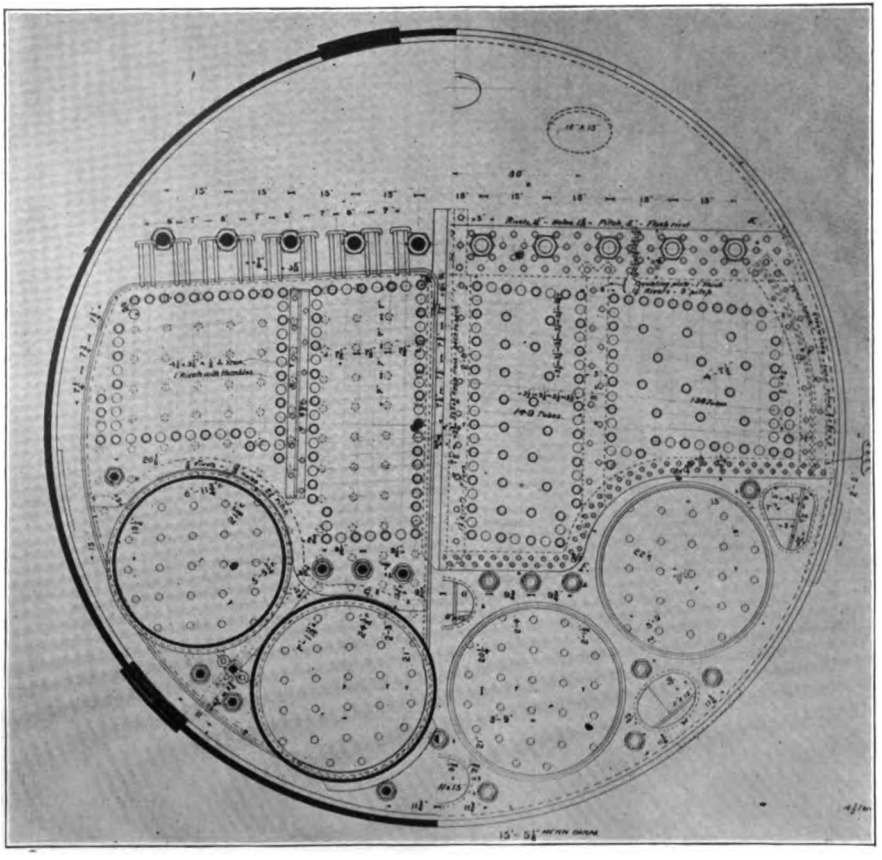

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Water surface, 4 ins. above highest heating surface, 21-ft. boiler, sq. ft..	284.75
19-ft. boiler, sq. ft..	258
Smoke pipes (2), diameter, feet and inches	8–0
area of both, square feet	100.6
height above lowest grates, feet	87
Number and diameter of safety valves (2 on one base), inches	4 of $4\frac{1}{4}$
Diameter of boiler main stop valves, inches	$9\frac{1}{2}$
auxiliary stop valves, inches	7
Totals for three boilers:	
Heating surface, tube, square feet	14,096
plate, square feet	2,595
total, square feet	16,691
Grate surface, square feet	513.6
Area through tubes, square feet	71.4
over bridge walls, square feet	73.5
Volume of furnaces and combustion chambers above grates, cu. ft.	2,123
steam room, cubic feet	2,240.5
Area of water surface, square feet	800.75
Ratios:	
Tube H.S. to G.S.	27.44
Plate H.S. to G.S..	5.05
Total H.S. to G.S.	32.40
Area through tubes to G.S.	.139
Volume of furnaces and combustion chambers above grates to G.S..	4.13
Steam room per square foot of G. S.	4.36

SINGLE-ENDED BOILERS.

Length, feet and inches	9–$11\frac{1}{2}$
Diameter, outside, feet and inches	15– 8
Thickness of shell, inches	$1\frac{7}{16}$
heads, top, inches	$1\frac{7}{16}$
bottom, inch	$\frac{3}{4}$
tube sheets, inch	front $\frac{7}{8}$, back $\frac{3}{4}$
furnaces, inch	$\frac{9}{16}$
Combustion chambers, number in each boiler	2
thickness of plates, inch	$\frac{9}{16}$
depth at top, inches	$27\frac{1}{2}$
Furnaces, greatest internal diameter, feet and inches	3– $5\frac{7}{8}$
least internal diameter, feet and inches	3– 3
length of grate, feet and inches	6– 7
number in each boiler, corrugated	4
Tubes, outside diameter, inches	$2\frac{1}{4}$
length between tube sheets, feet and inches	6– $6\frac{3}{8}$
Tubes, number of ordinary	428
stay	164
spaced vertically, inches	$3\frac{1}{4}$

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Tubes, spaced horizontally, inches	$3\frac{1}{2}$
thickness of ordinary, B.W.G. No. 10, inch	.132
stay, B.W.G. No. 6, inch	.203
Diameter of rivets in shell sheets, inches	$1\frac{5}{16}$
screw stays, inches	$1\frac{1}{2}$
Pitch of screw stays, inches	7 and $7\frac{1}{2}$
Number and diameter of through upper braces, inches	10 of $2\frac{3}{4}$
lower braces, inches	3 of $1\frac{3}{4}$
braces from head to back tube sheets, inches,	14 of $1\frac{3}{4}$
Heating surface, tube, square feet	2,280
plate, square feet	426.4
total, square feet	2,706.4
Grate surface, square feet	85.6
Area through tubes, square feet	12.42
over bridge walls, square feet	12.25
Volume of furnaces and combustion chambers above grates, cubic feet,	349
Steam room, water four inches above highest heating surface, cu. ft.	355
Water surface, water four inches above highest heating surface, sq. ft.	116
Number and diameter of safety valves (2 on one base), inches	2 of $4\frac{1}{2}$
Diameter of boiler stop valves, inches	7
auxiliary stop valve, inches	6
Totals for two boilers:	
Heating surface, tube, square feet	4,560
plate, square feet	852.8
total, square feet	5,412.8
Grate surface, square feet	171.2
Area through tubes, square feet	24.84
over bridge walls, square feet	24.50
Volume of furnaces and combustion chambers above grates, cubic feet,	698
steam room, cubic feet	710
Area of water surface, square feet	232
Ratios:	
Tube H.S. to G.S.	26.63
Plate H.S. to G.S.	4.92
Total H.S. to G.S.	31.62
Area through tubes to G.S.	.145
Volume of furnaces and combustion chambers above grates to G.S.	4.07
Steam room per square foot of G.S.	4.14

ALL BOILERS.

Heating surface, tube, square feet	18,656
plate, square feet	3,447.8
total, square feet	22,103.8
Grate surface, square feet	684.8
Area through tubes, square feet	96.24
over bridge walls, square feet	98.00

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Volume of furnaces and combustion chambers above grates, cubic feet,	2,821
steam room, cubic feet	2,950.5
Area of water surface, square feet	1,032.75
Ratios:	
Tube H.S. to G.S.	27.24
Plate H.S. to G.S.	5.03
Total H.S. to G.S.	32.28
Area through tubes to G.S.	.14
Volume of furnaces and combustion chambers above grates to G.S.	4.11
Steam room per square foot of G.S.	4.31

Forced Draft.—The closed fire-room system of forced draft is used. The air is supplied by eight Sturtevant blowers, one in each fire room. The fans are driven by two-cylinder, vertical, simple, enclosed engines with cranks at 180 degrees.

Diameter of steam cylinders, inches	5
Stroke, inches	4
Diameter of fan, inches	60
Width of fan at rim, inches	14
Area of induction nozzle, square inches	1,060.7
Area of eduction nozzle, square inches	2,220

Feed Pumps.—There are two main and four auxiliary feed pumps, all of the Admiralty type, Worthington duplex, and all of the same size, 10 inches by 7 inches by 12 inches, with a capacity of 400 gallons per minute. The main feed pumps are located one in each engine room and draw water from the feed tanks and air-pump suctions and deliver to the boilers; the auxiliary feed pumps draw from the feed tanks, the air-pump suctions, the sea, the drainage system and the boilers, and discharge into the boilers, fire main or overboard. These pumps are located one in each of fire rooms Nos. 3, 4, 5 and 6. The discharges of the main and auxiliary pumps are not connected, the auxiliary feed pumps only feed through the auxiliary feed main. In the port after fire room there is a small duplex Worthington pump, 4½ inches by 3 inches by 4 inches, of 65 gallons per minute capacity, for feeding the auxiliary boilers in port.

Fire and Bilge Pumps.—In each engine room there is a vertical, duplex Worthington pump which draws from the sea, the

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bilge and the drainage system, and delivers into the fire main or outboard. The steam cylinders are 10 and the water cylinders 7 inches in diameter; stroke, 12 inches.

Water-Service Pumps.—In each engine room there is a vertical, duplex Worthington pump which draws from the sea, and delivers into the water-service pipes, the distiller circulating pipes, and into the fire main. These pumps have a capacity of 400 gallons per minute; size, 10 inches by 7 inches by 12 inches.

Bilge and Sanitary Pumps.—There are two single-acting plunger pumps on each main-engine shaft, driven by eccentrics; one pump on each shaft is arranged to draw from the bilge and discharge overboard; the other to draw from the sea, and discharge into the flushing main.

Grease Extractors.—A grease extractor is fitted on the discharge of both main feed pumps. It is similar in action to a Macomb strainer; the cartridge is perforated and covered with burlap, through which the water filters. By-pass valves are fitted so that the extractors may be overhauled without interrupting the boiler feed.

Feed Tanks.—There is a feed tank of 2,000 gallons capacity in each engine room. A part of the tank is fitted as a filter, into which the water from the air pumps is delivered. The filter has a movable cover and is provided with sponges. Each tank has a manhole, glass water gage, shut-off and drain cocks. An overflow pipe is fitted and so arranged that any water passing down it may be seen. Each feed-pump suction is provided with a balance valve operated by a float in the feed tank, and so arranged that no air will enter the feed pipes.

Ash Hoists.—In each fire-room hatch there is a Williamson Bros. double, reversible ash hoist, by means of which one bucket of ashes of 300 pounds (with a steam pressure of 80 pounds) can be hoisted in five seconds. The steam cylinders are 4½ inches in diameter, with a stroke of 4½ inches.

Steam Traps.—The separators, the jackets, the main and auxiliary steam pipes, the radiators, and all places where condensed steam can accumulate are fitted with drain pipes and locks, or valves, and with automatic traps which discharge into the feed

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tanks. The traps are provided with by-pass pipes and valves for convenience in overhauling.

Engineer's Workshop.—The workshop is situated on the splinter deck, just forward of the engine rooms. It is fitted with a vertical engine, 7 inches by 7 inches, a 24-inch lathe, a 14-inch screw-cutting lathe, a shaping machine, a double-geared drilling machine, a hand drill press, combined punch and shears, and emery wheels.

Distilling Apparatus.—There are two Williamson Bros. straight-tube distillers, and two evaporators, Bureau pattern, with a combined capacity of 7,500 gallons of potable water at a temperature of 90 degrees Fahrenheit per day of 24 hours. The water-service pumps are used for the distiller-circulating water. There are two distiller feed pumps of the Worthington horizontal, duplex type, two combined brine and fresh-water pumps of the same type, and two trap pumps of the same type, except that they are vertical. There are two filters and two water meters fitted.

Ice Machine.—There is an Allen dense-air ice machine capable of producing the cooling effect of one ton of ice per day; steam cylinder, 9 inches; air-compressor cylinder, 5¾ inches, and air-expander cylinder, 4¾ inches in diameter; stroke, 10 inches. The circulating, water and primer pumps are single acting, each 1⅝ inches in diameter and 10 inches stroke. The cooling pipes connect to the ice tank, to the refrigerating room and to the scuttle butt.

Ventilating Fans.—There is in each engine-room hatch a 50-inch steel-plate fan, driven by a 12-H.P. electric motor, for engine-room ventilation only. For the general ventilation of the ship there are eight 50-inch steel-plate fans, located two on the berth deck and six on the splinter deck, for supplying air to the various parts of the ship. These fans are each driven by 12-H.P. electric motors. There are also three small exhausters driven by 3-H.P. electric motors, located two on berth deck and one in the steering-engine space, for exhausting air from the crews' W. C., officers' W. C., and the steering-engine room. All the fans were furnished by the Sturtevant Company, and the electric driving motors by the General Electric Company.

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Steam Cutters.—There are two steam cutters, one 40 and the other 33 feet long. They have Ward boilers, type 5-G-1, round, and 5-D, square, respectively, compound engines and keel condensers. The cylinders for the 40-foot cutter are 5 and 10½ inches in diameter by 8 inches stroke, and those for the 33-foot cutter, 4 and 8 inches in diameter by 6 inches stroke.

Telegraphs and Revolution Indicators.—There is a Cory mechanical telegraph in each engine room connected to transmitters in conning tower and pilot house, and a mechanical gong in each engine room with bell pulls in the pilot house and on the flying bridge near the after bridge. Mechanical tell-tales are fitted in the conning tower and in the pilot house to show the direction of revolution of the main engines. In each engine room there is a mechanical indicator to show the relative speed and direction of revolution of the propellers on one dial.

Telephones and Voice Pipes.—For communication between the various parts of the ship there is a complete system of telephones and voice pipes with call bell. All battle stations are connected direct to the conning tower and central station. The central station is provided for use in battle and in case of accident to conning tower.

Steering Engine.—On the after platform deck there is a Williamson Bros. combined hand and steam-steering engine: cylinder, 14 inches diameter; stroke, 11 inches. The engine is connected to a horizontal fore-and-aft shaft, on the after end of which there is a right and left-hand screw. The screw works in the crossheads, one on the starboard and one on the port side, the rudder yoke being connected by rods to these crossheads. With the steam gear the rudder can be put from hard over to hard over in 20 seconds when the ship is going full speed. The engine is controlled from the conning tower and the pilot house by means of a hydraulic telemotor or by wire ropes.

Steam Windlass.—In the windlass house forward of the forward turret there is a steam windlass. The engine is reversible, double-cylinder, vertical, direct-acting, with cylinders 15 inches in diameter, and a stroke of 14 inches. The windlass is fitted with two wild cats to take the chains.

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Steam Winch.—There is a double-cylinder steam winch in the windlass house forward of forward turret. The cylinders are 8 inches in diameter; stroke, 8 inches. The winch is fitted with two drums for taking hawsers.

Electric Plant.—The installation consists in general of seven generating sets, 750 incandescent lights, 4 search lights, 2 sets of signalling apparatus, 1 main switch board, 3 main distribution boards, 7 auxiliary distribution boards, together with the necessary wire, wiring accessories, molding and fixtures and the motors given in table. The seven generating sets were made by the General Electric Company. In each set there is a 50-kilowatt dynamo of multipolar type, having a capacity of 625 ampères at 80 volts, compound-wound six-pole. The engines driving the dynamos are compound, tandem, vertical, inverted; diameter of cylinders, 10½ and 18 inches; stroke, 8 inches. The engines are designed to run with full load at 310 revolutions per minute with 110 pounds steam pressure. The bed plate is common to both engine and dynamo. The incandescent lights are of 16 and 32 candle power, designed for 80 volts.

Each of the dynamos are connected to the main switch board, and to the equalizer board. The main switch board, containing only the panels for the dynamos and lighting and motor bus bars, distributes the current to the main distribution boards, which contain the switches of lighting circuits and motor feeders. The auxiliary distribution boards receive current from main distribution boards, and are for motors only.

The ship is wired on the three-wire system, with 80 volts between neutral wire and each leg, and 160 volts between outside legs. This gives a smaller amount of copper than would be necessary in the two-wire system and a wider range in speed of the motors, which are generally wound for both 80 and 160 volts.

There are four search lights, made by the General Electric Company, two mounted on a platform on the mainmast and two on a platform on the foremast. The projectors are 30 inches in diameter, and hand controlled. All lamps are of the horizontal type with combination hand or automatic feed, and designed for

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a current of 75 to 90 ampères at about 50 volts. The carbon holders are adjustable and the life of the carbon is six hours.

The signal apparatus is in two sets, one for each mast, of the usual Ardois type, and consists of four double signal lanterns to each set, cable connections and key board on the forward and after bridges.

Electric speed indicators and transmitters are fitted in the pilot house and in conning tower; also, electric helm indicators and electric steering-engine telegraphs.

There are thermostats in each coal bunker and in certain store rooms, with an annunciator on bulkhead forward of cabin.

ELECTRIC MOTORS.

Name.	Number.	Horsepower.	Revolutions.	Volts.	Ampères.
Upper-deck winches	4	25	320	80 or 160	150
Main-deck winches	2	25	320	80 or 160	150
Forward boat cranes	2	50	400	80 or 160	265
After boat cranes	2	20	350	80 or 160	111
Ventilating fans	10	12	500	80 or 160	64
Small exhausters	3	3	1,030	80	35
Turret turning	4	50	400	80	600
13-inch ammunition hoist	4	20	350	80 or 160	111
8-inch ammunition hoist	4	6	375	80 or 160	37
5-inch and 6-pdr. chain ammunition hoist	10	3.75	375	80 or 160	22
6-pounder winch ammunition hoist	2	6	375	80 or 160	37
13-inch elevating	4	2.5	300	80	30
13-inch rammer	4	5	775	80	60

Pneumatic Plant for Torpedoes.—There are two 9½-inch by 4-inch duplex torpedo compressors with the three-stage air cylinders and two accumulators. Both compressors and accumulators are on the splinter deck, one of each forward and aft. The compressors were made by the Rand Drill Company.

OFFICIAL SPEED TRIAL.

The official speed trial took place off the New England coast on Monday, September 25, 1899. It consisted of two runs over a measured course of 33 nautical miles. The time occupied in

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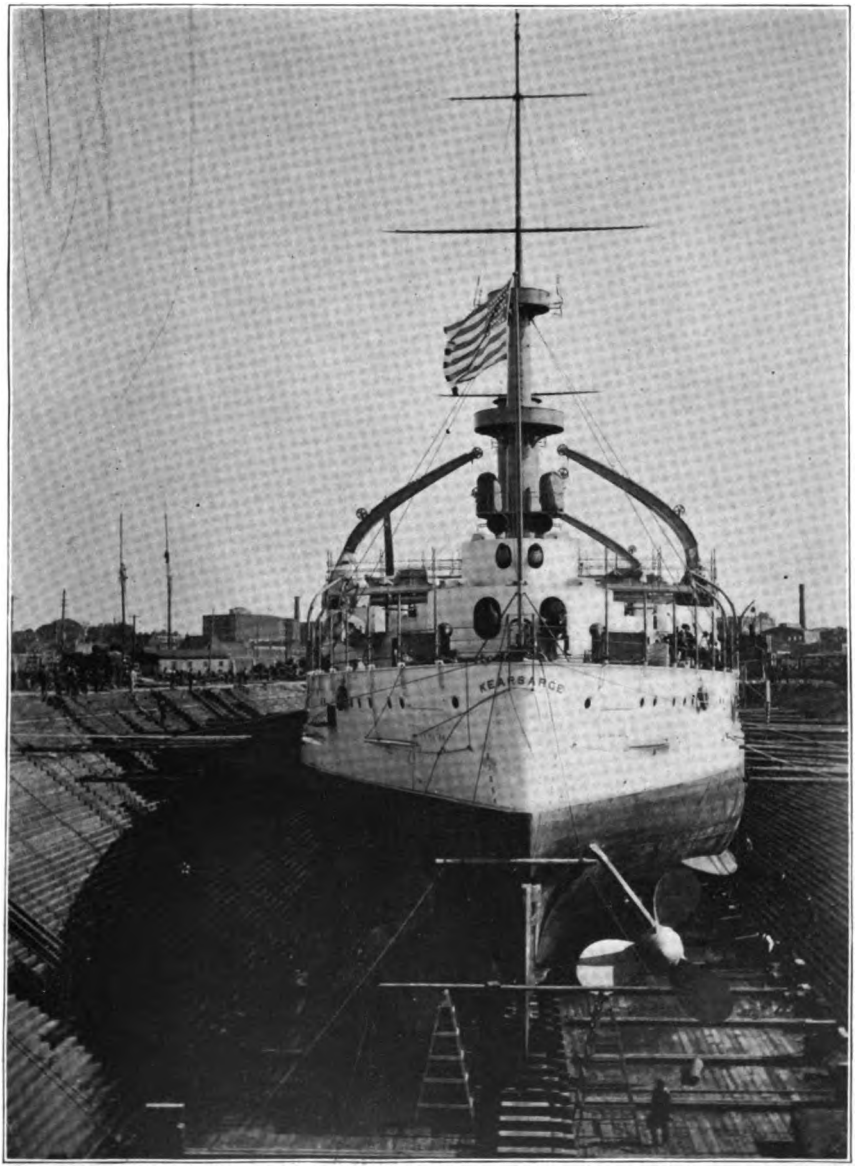

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making the first run (to the northward,) was 1 hour 54 minutes and 19 seconds, and the return run, 2 hours and 55.5 seconds. Total time in making the two runs, 3 hours 55 minutes 14.5 seconds. Tidal corrections applied to the trial run made the true mean speed 16.816 knots. The weather was fair, brisk to fresh breeze from southeast, and considerable sea while going north; strong southeast wind with lumpy sea and hazy weather on return run. At the end of run, with both engines full speed ahead, the helm was put hard to port and the turn made in two and one-half times her length and came inside her own circle. All boilers were in use under forced draft, all fire rooms being connected. All the steam generated was used by the main engines and auxiliaries except that used in the steering engine, ice machine, and in the engine for the dynamo to light the engine and boiler compartments. The coal used was hand-picked Nuttalberg coal from the New River region. The boilers and engines worked well throughout the run barring one accident (the bursting of several tubes in the port feed-water heater), which happened during the run north and which indisputedly prevented the ship from making an average of at least 17.25 knots. No water was used at any time during the run on the main engines. All the auxiliaries worked well.

The engineer force during the trial consisted of the following:

7 engineers.
6 water tenders.
10 machinists.
24 oilers.
6 apprentices.
3 dynamo oilers.
3 pumpers.
3 storekeepers.
3 ice-machine men.
29 firemen.
29 coal heavers.
5 boiler makers.

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After the trial the boilers, main engines and auxiliaries were examined and reported in good condition, except the feed-water heater above mentioned.

OFFICIAL TRIAL TRIP OVER COURSE FROM CAPE ANN TO CAPE PORPOISE. DISTANCE, 33 NAUTICAL MILES AND RETURN. SEPTEMBER 25, 1899.

No. station.	Chronometer time.			Elapsed time.	Speed, knots.	Formula used: D = Distance between stations. E = Elapsed time in minutes. S = Speed.
	h.	*m.*	*s.*			
1	3	23	10.5	.....	...	$S=\frac{D\times 60}{E}=\frac{6.6\times 60}{22.625}=\frac{396}{22.625}=17.50$
				22 *m.* 37.5 *s.*		
2	3	45	46	22.625	17.50	
				22 *m.* 37.5 *s.*		
3	4	08	25.5	22.625	17.50	
				23 *m.* 10 *s.*		
4	4	31	35.5	23.166	17.09	
				23 *m.* 4.5 *s.*		
5	4	54	40	23.075	17.16	
				22 *m.* 49.5 *s.*		
6	5	17	29.5	22.825	17.35	
				1 *h.* 54 *m.* 19 *s.*	17.32*	
				RETURN.		
6	5	41	9.5			
				24 *m.* 3 *s.*		
5	6	05	12.5	24.05	16.47	
				23 *m.* 49 *s.*		
4	6	29	1.5	23.816	16.63	
				24 *m.* 11 *s.*		
3	6	53	12.5	24.166	16.385	
				24 *m.* 37.5 *s.*		
2	7	17	50	24.625	16.08	
				24 *m.* 15 *s.*		
1	7	42	05	24.25	16.33	
				2 *h.* 0 *m.* 55.5 *s.*	16.379*	

* Average speed.

17.32
16.38

2) 33.70

16.85 Average speed for both ways.

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US B.S. No. 5 Kearsarge.

Card No. 6. Starbd. Engine. Sept. 25. 1899. - OFFICIAL TRIAL

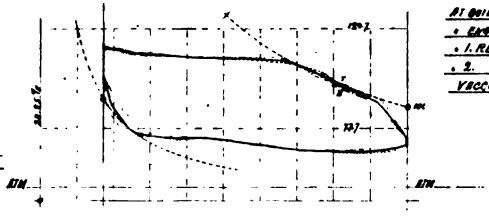
Corrected for actual Cylinder Dimensions.

NO LIVE STEAM ADMITTED TO I P Cylinder.

STEAM PRESSURES.

AT BOILER.	—	Gauge.	—	absolute
" ENGINE	170	"	184.7	"
" 1. RECEIV	63	"	77.7	"
" 2. "	12	"	26.7	"
VACCUUM.	24.8		312	B.P.

H P Cyl.
SCALE 80.



M. E. P.

EACH Cylinder.		Reduced to L P	
H.P	76.976	13.912	32.84%
I. P.	34.908	14.828	35.00 "
L. P.	13.625	13.625	32.16 "
TOTAL		42.365	100.00 "

I P Cyl.
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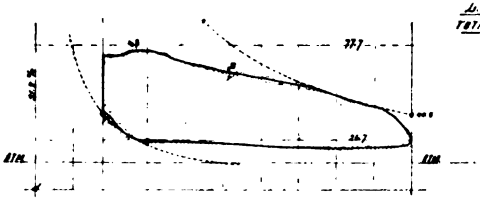
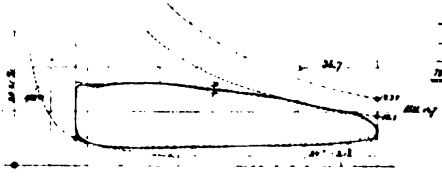


Revolutions 110.
Piston speed 880.

I. H. P.

H.P.	1764.0
I. P.	1880.0
L. P.	1727.5
TOTAL 1 and	5371.5 I.H.P

L P Cyl
SCALE 20



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U.S. B.S. No. 5. - Kearsarge.

Card No 6. Starboard Engine. Sept. 25. 1899. Official Trial.

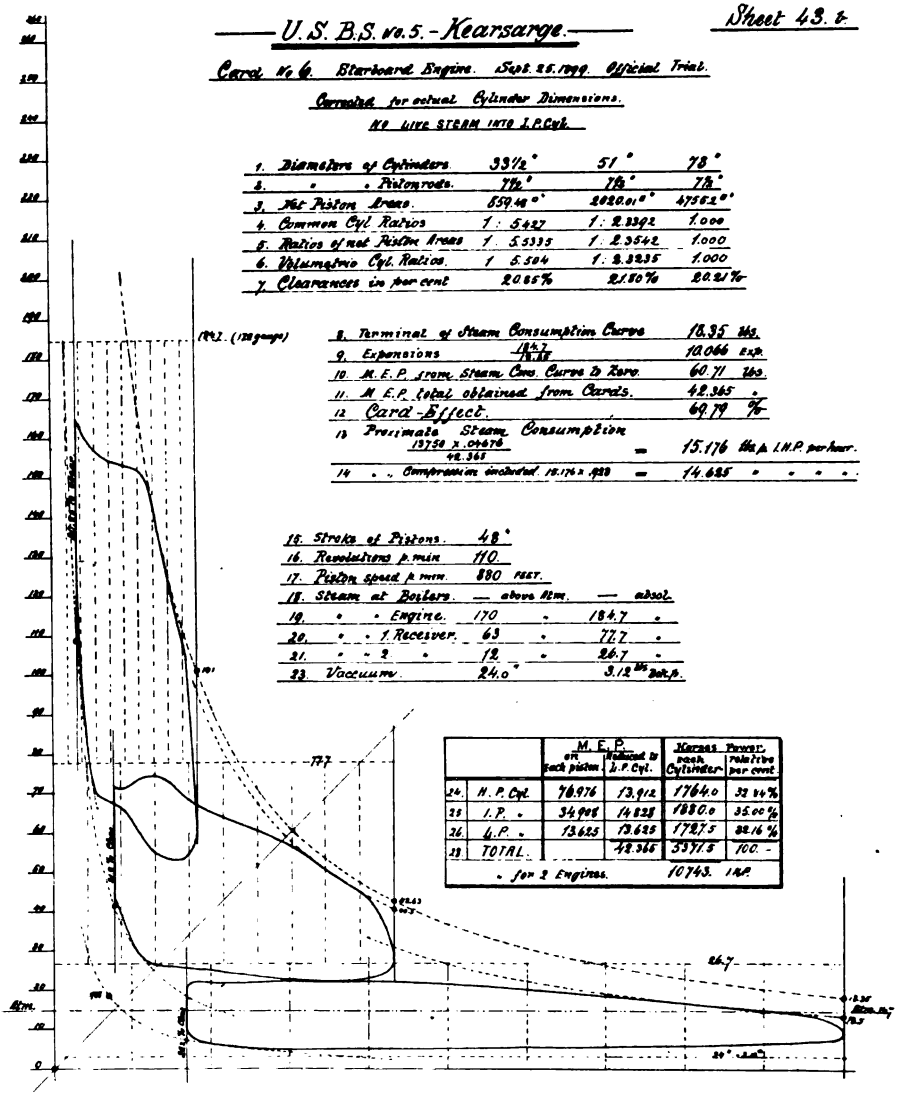
Corrected for actual Cylinder Dimensions.

NO LIVE STEAM INTO I.P. Cyl.

1. Diameters of Cylinders	33½"	51"	78"
2. " " Piston rods.	7½"	7½"	7½"
3. Net Piston Areas.	859.46"	2020.01"	4756.2"
4. Common Cyl. Ratios	1 : 5.427	1 : 2.3392	1.000
5. Ratios of net Piston Areas	1 : 5.5335	1 : 2.3542	1.000
6. Volumetric Cyl. Ratios.	1 : 5.504	1 : 2.3235	1.000
7. Clearances in per cent	20.85%	21.80%	20.21%

8. Terminal of Steam Consumption Curve	18.35 lbs.	
9. Expansions $\frac{184.7}{18.35}$	10.066 exp.	
10. M.E.P. from Steam Cons. Curve to Zero.	60.71 lbs.	
11. M.E.P. total obtained from Cards.	42.365 "	
12 Card-Effect.	69.79 %	
13 Proximate Steam Consumption $\frac{13750 \times .04676}{42.365}$ =	15.176 lbs. p. I.H.P. per hour.	
14 " " Compression included. 15.176 × .929 =	14.625 " " " "	

15. Strokes of Pistons.	48"		
16. Revolutions p. min.	110.		
17. Piston speed p. min.	880 FEET.		
18. Steam at Boilers.	— above Atm.	— absol.	
19. " " Engine.	170 "	184.7 "	
20. " " 1. Receiver.	63 "	77.7 "	
21. " " 2. "	12 "	26.7 "	
22. Vacuum.	24.0"	3.12 lbs. Bar. p.	



		M.E.P. on each piston	M.E.P. Reduced to L.P. Cyl.	Horses Power each Cylinder	Horses Power relative per cent.
24.	H.P. Cyl.	76.976	73.912	1764.0	32.44%
25.	I.P. "	34.998	14.825	1880.0	35.00%
26.	L.P. "	13.625	13.625	1727.5	32.16%
27.	TOTAL.		42.365	5371.5	100.-
" for 2 Engines.				10743. I.H.P.	

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CONTRACT TRIAL DATA.

Draught of water, beginning of trial, forward, feet and inches	23– 4
aft, feet and inches	23–10
end of trial, forward, feet and inches	23– 2
aft, feet and inches	23– 8
mean, forward, feet and inches	23– 3
aft, feet and inches	23– 9
average on trial, feet and inches	23– 6
Displacement (mean), tons	11,550
Area immersed midship section, square feet	1,618
Wetted surface, square feet	33,700
Mean speed, knots per hour	16.816
I.H.P., main engines only	11,674.3
main engines, air, circulating and feed pumps. (B)	11,787.856
all machinery in use	11,954.37
Speed^3 × area immersed midship section ÷ I.H.P. (B)	652.67
Speed^3 × displacement$^{2/3}$ ÷ I.H.P. (B)	206.11
I.H.P. per 100 square feet wetted surface, (B)	34.98
Screw propellers, number	2
number of blades each	3
diameter, feet and inches	16– 9
helicoidal area, square feet	84.2
pitch on trial, feet and inches	17– 3

SYNOPSIS OF STEAM LOG.

		Starboard.	*Port.*
Slip of screws, per cent		12.93	13.3
Revolutions of main engines per minute		113.6	114.5
mean		114	
Piston speed, feet per minute		908.8	916
Steam pressure (mean) at engines		172.4	169
first receiver, absolute		79.6	82.4
second receiver, absolute		28	29.7
Vacuum in condenser, inches		24.6	24.5
Throttle-valve opening		Wide.	
Steam cut-off in fraction of stroke from beginning,	H.P	.67	.66
	I.P	.72	.71
	L.P.	.70	.69
Temperatures in degrees Fahrenheit,	Engine rooms	88.1	
	Injection	61	61
	Discharge	125.3	125.3
	Feed at tank	124.7	139.8
Air pressure in fire rooms in inches of water		1.089	
Mean effective pressures,	H.P	79.75	79.78
	I.P	36.94	35.75
	L.P	14.63	14.635
Aggregate equivalent pressure referred to L.P. piston		44.74	44.23

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		Starboard.	*Port.*
Revolutions or double strokes per minute,	Main air pumps	17.1	27.4
	Main circulating pumps	134.6	178
	Main feed pumps, average	34	
	Eight forced-draft blowers, av'ge.	427	
I.H.P.	H.P. cylinder	1,887.07	1,894.63
	I.P. cylinder	2,055.80	1,996.45
	L.P. cylinder	1,916.92	1,923.43
	Collective, each main engine	5,859.79	5,814.51
	Main air pumps, each	9.116	10.54
	Main circulating pumps	11.52	22.38
	Four main boiler feed pumps	60	
	Eight forced-draft blowers	76.512	
	Other auxiliaries	90	
	Collective, main engines, air, feed and circulating pumps (B)	11,787.85	
	Total all machinery in use	11,954.37	
Square feet cooling surface (2) main condensers		14,100	
per I.H.P. main engines		1.18	
Heating surface in use		22,103.8	
Grate surface in use		684.8	
Square feet total H.S. per total I.H.P.		1.849	
I.H.P. per square foot grate surface, total		17.45	
ton machinery (penalty weight)		10.64	
Kind of coal		New River (picked).	
Pounds per hour, total		28,209.5	
I.H.P., all machinery		2.36	
main engine, auxiliary, circulating and feed pump		2.39	
square foot grate surface		41.18	
heating surface		1.276	

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THE ANNUAL REPORT OF THE ENGINEER-IN-CHIEF.

There is so much important matter in Admiral Melville's report this year as to make it advisable to reprint in our pages a considerable portion of it, especially as so many of our associates and subscribers never obtain more than the synopses of Bureau annuals as are printed with more or less fullness in the current press.

It is well for our Society to have a clear idea of the extent and importance of the technical work of the Bureau of Steam Engineering, particularly at a time when considerable publicity has been given to schemes for the combination of the "working bureaus" of the Navy—these being understood as including the Bureaus of Steam Engineering, Equipment, Ordnance, and Construction and Repair. That such a combination is antagonistic to efficiency, as understood by the outside shipbuilding world, goes without saying, but, nevertheless, the full scope of the actual work of each bureau is known to far too few of those who take interest in general naval engineering.

Besides detailing this work Admiral Melville significantly touches on the questionable points in the operation of the Personnel Bill, and also takes up, in extenso, the subject of electrically-driven auxiliaries on ship board. This latter section has called forth some editorial criticisms from the "Electrical World," which appear to us to be cynicism born of disbelief in the Personnel Bill rather than any refutation of the statements of the Engineer-in-Chief.

Interesting data of tests of machinery, etc., are given, and the report includes several plates of proposed machinery for the new cruisers, 14 to 19, which we are unable to reproduce at this time.

The following extracts contain the most important parts of the report.

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GENERAL OPERATIONS OF THE BUREAU.

While the legislation of the last Congress provided for an increase of the Navy by appropriating for three seagoing coast-line battleships, three armored cruisers and six protected cruisers, the limitations placed upon the price of the armor and the clause which prevented contracts being made for the hull until the armor for the first two classes of the above vessels had been contracted for, presented insuperable obstacles in the way of proceeding promptly with the building of the same, the price of armor mentioned in the bill being far below that for which any manufacturer would deliver it.

On this account the immediately necessary designing work in this Bureau upon new ships was confined to plans for the machinery for the six protected cruisers, as will be noted under the head of work in the drawing room.

Plans of general arrangement of machinery for the armored cruisers, however, have been pursued to such a degree as is warranted by the available outlines, so that when the matter of cost of armor is adjusted and further progress of plans justified the completion of the designs will be a matter requiring but little time.

The usual extensive and laborious duty connected with the working out of details for machinery already under construction, and the examination and correction of designs submitted by contractors, have been continued in a manner highly satisfactory in results. The matter of designing the internal arrangements of machine shops at New York, Port Royal, Key West and Mare Island has also demanded considerable attention, in order to provide for the most efficient disposition of tools when installed.

In my last annual report I alluded to the extraordinary conditions which were then prevailing, and included the general items of importance in the machinery-repair work of this Bureau up to the date of writing that report, October 1, 1898, at which time the cessation of hostilities had about taken effect. Necessarily the results of the extraordinary duties of the various ships under such circumstances were not fully realized by the Bureau until the return of the fleets to the repair stations, but it was a matter

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of gratifying surprise to the Bureau to find the extent of needed repairs as limited as it was, being generally confined to portions of the machinery such as boiler tubes and condenser tubes, which are most readily affected by the extreme conditions prevailing in war times. The generally excellent condition of the engines of our ships after these trials is a reflection of a highly complimentary character upon the Bureau's control of the designs of the machinery and upon the efficiency of the officers under whose direct charge their operations were conducted.

The matter of completely repairing all the ships, both of the regularly Navy and those retained from the auxiliary fleet, was taken promptly in hand as ships returned to the various yards, and the aggregate cost assumed small proportions compared with what might have been anticipated. Most of this work has now been effected, and yet, owing to the unexpected retention of very many of the auxiliary ships for use in naval service, the estimates made by the Bureau in the last annual report for current expenses, 1899–1900, fell far short of the amount actually required, as at the time of the report it was the general impression that upon the close of the war most of the auxiliary ships would be sold or otherwise disposed of. A portion of the large balance remaining in the Treasury from the emergency fund under this Bureau (between two and three millions) could be very properly reappropriated for this unanticipated work, by special legislation, and obviate the necessity of asking for further provision for current work in the coming deficiency bill. I desire to call your attention to the above circumstances in view of the necessity of thus further providing for the expenses of the present fiscal year.

The general lessons from the war were in no way indicative of any desirable change in the machinery of our ships, with the exception of increasing the evaporating plants, and the adoption, with all practical and economical promptness, of the water-tube type of boilers. The matter of increasing the evaporating plants has been expeditiously accomplished, and at present these individual plants on shipboard are about equal to any anticipated emergency. As regards the adoption of the water-tube type of boiler, the Bureau is progressing with such proper speed as is

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necessary to avoid mistakes, and to obviate sacrifice of still useful boilers of the older type. As fast as the present outfit of Scotch boilers becomes unreliable or inefficient, the newer type is being substituted. This has obtained already on the *Alert*, *Atlanta* and *Chicago*, and a further substitution of Babcock & Wilcox type of water-tube boilers for the old Scotch boilers on the *Cincinnati* and *Raleigh* is in active progress. These steps are important and are the direct results of the unqualified success of this type of boiler on the *Marietta* and *Annapolis* in our own service and on various other ships not of the Navy, and renders their adoption, to the extent already made, absolutely safe. Much interest also attaches itself not only to the trials of the battleships now building, which will have the Niclausse and Thorncroft types of water-tube boilers, but especially to the future preservation of the several types of these boilers during the years of that ordinary naval service which will not call for more than a very limited use of the entire plant. The status of water-tube boilers at the present time is much more doubtful regarding the possibilities of protection from deterioration while not in use than regarding their efficient output during actual service. This ability or inability to properly protect such boilers is of most vital importance, and largely governs the annual cost of repairs to naval machinery.

I would call attention to the completion of the *Rainbow* as a second distilling ship and also to the success with which the *Iris*, the first distilling ship, has been operated. This latter is noted under its separate heading in this report.

While not desiring to allude prominently again to the *Vulcan* or its work as a repair ship (the subject having been fully exhausted in my last report and in the public periodicals), I can not pass this by without again urging the advisability of properly designing and building a repair ship, which, while being constructed with a view to the utmost efficiency for such service in times of emergency, may be retained without use (in ordinary) and without serious deterioration for many years. The promptness with which the *Vulcan* was fitted up during the first excitement of the war does not indicate that a waiting policy is the wisest one, for

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by accident alone the absolutely necessary work demanded of that ship was well within her capacity. There is no good reason for failing to provide a ship which would be even far more efficient than the *Vulcan* was and one perfectly self-sustaining in any climate or location. The *Vulcan* herself proved to be of but temporary fitness, as, after the war, the hull was found to be in such bad condition as to make it proper to strip the vessel and effect her sale.

During the year a number of torpedo boats have been completed and turned over to the Government, a synopsis of their trials being herein placed under separate headings.

Among the special items of navy-yard work on naval vessels I would note the following, a complete list of all vessels repaired being included elsewhere under separate yard headings:

Chicago.—Installation of new machinery completed, trials successfully made and ship sent on a regular cruise.

Atlanta.—Reconstruction of machinery and installation of new boilers practically completed, and ready for steam trial.

Cincinnati and *Raleigh.*—Preliminary work on complete rearrangement of fire-room plants and improvements in entire conditions obtainable in machinery spaces. The space originally allotted for the boilers of these two ships was not governed by a full appreciation of the requirements for successfully operating the plant. The limits of the machinery compartments were fixed in a certain arbitrary proportion, and the problem forced upon this Bureau of installing the requisite power to secure a specified speed. This was accomplished only at a sacrifice of operating space, and the well-foreseen results were that the fire rooms were almost unbearably hot under full-power conditions. A change recommended by me and prompted by economy was to remove two auxiliary boilers and spread the remaining boilers to advantage in increasing fire-room space available for working the fires, but the decision of the Board on Construction, now approved, has included a replacement of the entire Scotch boiler plant by water-tube boilers, and, with the increased pressure to be used, new H.P. cylinders are necessitated, of smaller diameter. Undoubtedly the result, while reducing the rated speed of these

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ships, will really increase the speed that can be properly maintained, and will greatly add to the efficiency of the vessels.

In powering a ship efficiently, and with a guaranty of securing readily the full I.H.P. of design, the space for machinery must be the primary consideration and a liberal allotment made for it according to the needs, not as gathered from published data of foreign ships (of whose actual working conditions we can never be sure), but from those known to be proper by this Bureau, whose professional experience and knowledge should be accepted without question.

Alert.—Installation of water-tube boilers is well in hand at Mare Island, Cal. The type selected is that of the Babcock & Wilcox Co. A test of one of these particular boilers was made prior to shipment from the works, under the direction of this Bureau and by its own officers, a synopsis of the test being included herein under tests and experiments. The showing was most satisfactory. In this change in the *Alert* it will be seen by the accompanying drawings that a saving in space and weight was made by which the coal capacity was increased by about 32 tons, and at the same time a somewhat greater horsepower was secured, owing to the ability to burn economically more coal upon the new grate surface than was possible upon the grate surface of the old boilers.

Mohican.—Old boilers removed from the *Swatara*, but still in efficient condition, were placed in this vessel, her old boilers having been condemned as worn out in service.

Hartford.—Installation of new machinery very nearly completed at this writing and an early dock trial expected. The work on this and preceding two ships has been done at the navy-yard, Mare Island.

Monterey.—Practical renewal of boilers (caused by pitting of tubes) is in hand. This ship has the Ward type of water-tube boiler, and the renewal in sections can be made without serious difficulty by the engineer force of the ship and without the necessity of tearing up the decks, a feature worthy of notice in connection with several of the types of water-tube boilers now being used by this Bureau.

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Iowa.—Complete retubing of boilers and condensers has been carried out.

Also the completion of the retubing of the boilers of the *Minneapolis* was included in the year's work.

The captured ships *Isla de Cuba*, *Isla de Luzon* and *Don Juan de Austria* have had extensive repairs to machinary done at Hongkong under contracts made by the commander-in-chief of the station under the emergency appropriation, and no doubt these vessels will render good service when finished.

In connection with special work, I desire to call your attention to several casualties which have occurred since my last report, in order that there may be no misconception of their import.

The *Wilmington* and *Helena* both have had mishaps to their propeller shafts, which, while not totally disabling the ships, indicate to the Bureau the propriety of installing new outboard shafts of greater strength. A large factor of safety was used in the design, but owing to the small diameter and great length of the outboard sections of these shafts they appear to have been greatly strained, probably more by springing and surging in a seaway than by the normal pressures brought upon them. New shafts are being made for both of these ships and will no doubt prove efficient.

The shafts of the *Marietta* and *Wheeling* have also proven defective through imperfect fitting of casings by the contractors, which permitted corrosion to take effect unseen beneath the brass. The present shafts of these ships are serviceable, but new end sections will be supplied as soon as possible for the *Marietta* in order to secure her against possible casualty, and new end sections for the *Wheeling* are now in the shops at Mare Island being fitted for that vessel.

Another casualty has been reported, viz: that of the cracking of the low-pressure cylinder liner of the port engine of the *Chicago*.

This did not materially disable the ship, although the first dispatches indicated that the low-pressure cylinder would have to be put out of use and the port engine run compound. The

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vessel has safely reached a home port, using the cylinder referred to, and necessary repairs will be made after careful examinations.

The after low-pressure cylinder frame of the port engine of the *Cincinnati* was broken while getting the ship under way, but the cause of the accident was not traced by the board which reported upon the same. The engines of this ship are of the four-cylinder, triple-expansion type, and the engines were readily and successfully operated after disconnecting the cylinder whose frame was cracked, so that return to the home port was but slightly delayed. These frames were cast iron.

One of the most serious casualties during the year was that resulting in the destruction by fire of the steam engineering buildings at the navy yard, New York, on February 15, 1899. The only buildings of the plant that were saved were the foundry, copper shop and a part of the boiler shop. It has apparently been impossible to locate the cause of this disastrous fire, but it is with no little pride that the Bureau points to the efficient manner in which its work was continued at that yard. The timely assistance afforded by the permitted use of the shops of other departments in the yard tided over the immediate difficulties, and with the greatest possible dispatch a temporary machine shop was erected on an adjacent lot and installed with such a complete tool outfit as has already enabled the Bureau to withdraw its force from all other shops in the yard and carry on its own work within its own buildings. At the same time all necessary steps were taken for the establishment of a new machinery plant at the yard, for which a prompt appropriation of $750,000 was made by the Congress, then in session. When finished this will undoubtedly be one of the most complete and efficient plants in the world, every advantage being taken of the latest devices of proven excellence.

The Bureau has seen fit to adopt an electrical drive for these shops in view of the advances made in that direction by the most progressive outside establishments, and also paying due attention to the indications of a still more rapid advance in the future. Contracts have been let for the power plant, and a most exhaust-

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ive requisition for proper outfit has been formulated after a thorough and extensive individual study of modern tools. In these shops no steam will be used outside of the power house proper, except for heating. The latest pneumatic appliances will also be installed where of established excellence and of economic advantage.

Close inspection of construction of machinery for new ships at the various shipyards has been maintained, and several tests and experiments of interest have been conducted by the Bureau, as noted under separate heading in this report.

PERSONNEL.

I approach the subject of the personnel with some hesitancy, owing to my inability to see indications of the desired result from the operations thus far of the personnel bill. It was my earnest hope that upon the taking effect of that bill the whole trend of detail would be toward the complete amalgamation of line and engineering interests in the Navy with the most favorable outlook for the protection of the rapidly advancing engineering science. My belief in the spirit of the bill was that it contemplated most essentially vast additions to the number of officers who would give earnest attention to engineering matters, and in no way aimed to augment the forces available for merely former line or deck duty. The comprehensive union of the line and engineering vocations I still hope will be the result of the personnel change, and I earnestly request that no Department regulations may be formulated or permitted to exist which will in any degree tend to destroy this belief or prevent such a construction of the intention of the bill. Briefly, the fate of the reconstruction of the personnel hinges upon the provisions made for future and continuous supply of efficient engineers in the Navy. The duties of the line were believed to be perfectly compatible with a professional excellence in engineering matters by an individual. A not unwarranted expectation is that preference for the mechanical part of these combined duties will be shown by a great number owing to the intense interest attaching itself to this field of work and to its almost universal application to the pro-

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gressive arts of the age. The only plausible scheme, therefore, is to insist upon the present line officer adapting himself as soon as possible to the new conditions, and increasing, where lacking, his knowledge of mechanical engineering. Primary instruction has already been given to every graduate of the Naval Academy. Necessary practice is easily attained. Departmental regulations insisting upon alternations for the present watch officers in deck and engine-room duties will accomplish the latter end. Efficient and complete instruction at the Naval Academy will enable the future line officer even more rapidly than now to grasp the new work and control it successfully. The practical instruction of the present watch officer, as above suggested, is a fundamental and vitally necessary feature which, in my opinion, should govern the rulings of the Department from now on.

I must invite your particular attention in this connection to the status of steam and mechanical engineering of to-day. Various outcroppings in the shape of electrical, hydraulic and pneumatic specialties divert the thoughtless into considering these fields fundamentally separate from that of steam engineering, while the fact remains that the man educated fully in "steam engineering" is in the very front rank of the advancing workers in such specialties. The principles of the side branches are of extreme simplicity, those governing the construction of the mechanisms being essentially the same as obtain in good mechanical engineering.

It is only necessary to push aside the more or less plausible superficialities which would lead to a misjudgment of these facts, and look for a moment upon the real requirements, to realize how fundamentally important and distinct are the duties of a mechanical bureau, and also to be convinced of the wisdom of using every exertion to provide the highest special talent for its future operation. I regret the matter of combination of bureaus has been even speculated upon. This regret, I assure you, in no way comes from motives other than the belief in the impossibility of a successful issue of such a scheme. Not only is the trend of modern mechanical work in all branches toward increased specialization, but the wisdom of such a trend is never questioned by the leading talent in the outside world of constructive work.

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I deem it pertinent in this connection to briefly review the character of the work of this Bureau and to note its increasing extent and importance in all branches.

The first and most important of the duties of the Bureau are those of superintendence of design of new machinery and of improvements to existing plants. The extreme accuracy necessary for and the numberless details attached to the design of modern power plants makes it absolutely requisite to have engineers of experience and ability as personal superintendents. The Bureau has heretofore carefully selected its men for this particular duty, and the results have proven the wisdom of the course pursued as well as the efficiency of these workers.

Following this work, and still pertaining to actual Bureau work, are the duties of overseeing methods of repair and desired improvements to existing machinery; guarding and adjusting the expenditures at the various stations for material and for new tools; developing the qualities of material by constantly studying the improvements in the manufacture of iron and steel and formulating the requirements in specifications, in order to secure to the Government the very best possible material; testing and experimenting with improved devices which give promise of economy, and of collating data by means of which machinery design is improved and work expedited.

The results of preserving this central control of the Bureau's operations are seen in the preservation of uniformity of design and in the adoption generally, in all the repair stations, of the very best methods of work, consequent upon which uniformity great economy to the Government ensues.

Besides this actual Bureau work, it is necessary to have representatives personally superintend the constructive and repair work to the machinery of ships at navy yards and stations. The experienced and educated engineer is nowhere more fitly placed than here. They act as skilled doctors for the disabled elements in the naval establishment, and wherever the guardianship of the Bureau's interests at such places is left to inefficient hands the results are speedily shown in the character of the repairs made. It is in the highest degree economical to have

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engineering talent of the highest order at the head of the steam engineering departments at these yards, so that ships sent forth from them in apparent cruising fitness may prove most truly to be so.

Of but slightly less importance is the superintendence of the work done by the shipbuilding yards on machinery for new ships. No one who has not studied the intricacies and difficulties connected with the installation of the power plant of a modern battleship can conceive of the numberless interferences while in course of construction which must be reconciled by personal superintendence, and always with a view to the efficient operation of the plant. Such a superintendence is of untold value, and makes all the difference between an ever available and ready vessel for service and one which is constantly seeking a navy yard for changes or repairs. Such work is necessarily arduous, and the limit of personal endurance must be considered in providing proper numbers.

After this, and clearly connected with it, comes the necessity of having inspectors at the producing mills for closely watching the output of material and attending to the physical and chemical tests of the same, in order that condemnation may not take place at the machine shops after transportation, and attendant long delays be experienced.

The following figures will give an idea of the great improvement in the manufacture of steel material for the engines and boilers of war vessels, brought about by the system of inspection now carried on, and aided by the desire of the American manufacturers to stand preeminent in this line of work, an ambition which frequently caused them to do work at a small profit or no profit at all, taking their reward in the advertisement gained and the prospect of future business.

The item of large engine forgings of steel, principally shafting, will illustrate the point in question, when we compare the steel specifications for the *Maine* and *Texas*, dated 1888 and 1889, respectively, with the requirements for the same class of material for battleships, monitors, torpedo-boat destroyers and torpedo

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boats now under construction, appropriated for by the act of Congress approved May 4, 1898.

The specifications for machinery steel for the *Maine* and *Texas* required a tensile strength varying from 56,000 to 70,000 pounds per square inch, with an elongation of from 16 to 20 per cent. in 2 inches, both depending on where the test piece was taken; while the specifications for the new vessels, dated 1898, just ten years later, require for high-grade shaft forgings, nickel-steel, oil tempered and annealed, a tensile strength of at least 95,000 pounds per square inch, an elastic limit of 65,000 pounds per square inch, with an elongation of 21 per cent. in 2 inches. All the shafting for torpedo boats Nos. 24 to 35 was made of this material, while in the battleships, monitors and torpedo-boat destroyers the crank shafts alone were made of nickel-steel, simply annealed, with a tensile strength of 80,000 pounds per square inch, an elastic limit of 45,000 pounds per square inch, with an elongation of 26 per cent. in 2 inches, the remainder of the shafting for these vessels being of the higher-grade quality previously mentioned. The possibility of thus reducing machinery weight without sacrifice of endurance and strength is clearly obvious.

One of the most important duties clearly under this Bureau, and one which the personnel bill has made even more important, if possible, than heretofore, is that connected with the instruction in engineering branches of the cadets at the Naval Academy. This special instruction in the combined course should never be left to the control of other than engineers of great practical experience as well as high theoretical attainments, and I deem it a privilege to guard the character of the course by nominating officers of peculiar fitness for this work.

Lastly, the apportionment of efficient officers to the ships in the Navy as heads of the steam engineering department is clearly one of moment, and illustrates in the present state of the roster the necessity of putting into effect such regulations as will immediately bring to the front officers of the former line best fitted for conducting such work, and which will lead to eventually producing the line engineer of experience who will be able to succeed to the positions of still higher importance noted above. I

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would ask that you take into consideration the vital importance of establishing alternation of deck and engine-room duty for the present watch officer of the line, in order that there may be no future shortcomings and no sad or disastrous deficiency in guarding these interests.

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After repeating his former recommendation that an Assistant Chief of Bureau be provided, Admiral Melville alludes to the subject of "Warrant Machinists" as follows:

* * *

WARRANT MACHINISTS.

I feel it necessary to draw your attention to the necessity of governing the duties of this new grade of mechanics in such a way as will secure to the service their continued skillful assistance as direct operators and repairers of machinery. With the official elevation which comes with a warrant there is not unreasonable apprehension that these men will desire a severance from actual manual care of the machinery of our ships, and will expect to act merely as engineering supervisors below. This, of course, would be wholly inconsistent with the interests of the service, as at no previous time in naval history has there been a greater demand for the highest mechanical skill in the persons of those who have direct charge of marine motive power. Clear and definite regulations are needed on this point at the start, in order that no ambiguity may foster discontent with simple duty or lead to hopes of further official elevation. The engineer officer is and must be the line officer of the future; the warrant machinist must recognize the necessity of his expert mechanical work as well as the distinction he is given by the reason of his excellence in it.

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WORK IN THE DRAFTING ROOM.

The inspection of designs submitted for machinery being built for new vessels of the Navy is a work requiring the closest attention and is in every sense arduous. With the forty-eight vessels actually in hand at the various shipbuilding establish-

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ments, the number of working drawings submitted is enormous, and it is to this feature of the drafting-room work that the Bureau desires to draw special attention in reference to a necessity for requesting increased force in clerical and drafting capacity.

I have included in my estimates for the coming fiscal year the item of salary for one chief draftsman at $2,250 per annum. Your favorable consideration is particularly requested for this item, as one which should not be omitted in the appropriation. The cost of this addition to the drafting-room force is most trifling compared with the resultant advantage of having a permanent expert head to the actual drafting force, who can work continuously under the experienced engineers in charge, and carry on without interruption the policy of the Bureau in design when by necessities of the service the officers have to be changed.

The experience drawn from numberless trials and reported necessities for change, for increasing efficiency of ships already commissioned, enables the Bureau to arrange plans for new ships with the greatest assurance of resulting excellence. This experience, however, does not extend itself to the drafting rooms of the shipbuilders, and constant changes in submitted designs are of necessity being made by the Bureau in order to preserve the very best conditions and to insure further efficiency. While carrying on this work of supervision and the attendant correspondence, there has been prepared also upon the drawing boards the following designs during the year:

Preliminary plans of machinery for battleships 13, 14 and 15, at a designed speed of 18½ knots.

Arrangement of machinery for armored cruisers 4, 5 and 6, with machinery plans for 22 knots.

Preliminary plans for 20-knot protected cruisers.

Plans and specifications of machinery for protected cruisers 14 to 19, drawings of which are attached to this report.

Machinery plans for ferry launch for Norfolk Navy Yard and Mare Island Navy Yard.

Minor plans for the *Chesapeake* auxiliary machinery.

Plans showing changes in machinery of various steam launches,

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the object of which is to secure interchangeability of parts of machinery for same sizes of launches.

Plans for minor changes in machinery of the *Fern* and *Katahdin*.

Complete layout and arrangement for new boilers in the *Cincinnati*, the change being made from the old Scotch boilers to Babcock & Wilcox water-tube boilers. The same general layout will apply equally to the *Raleigh*.

Plans in preparation for new high-pressure cylinders for the engines of the *Cincinnati*, made necessary by the higher pressures to be carried in the new boilers. This will also apply equally to the *Raleigh*.

Plans showing arrangement of water-tube boilers on the *Alert*.

Designs for new boilers for the tug *Triton* being built at the navy yard, Norfolk.

Changes in valve gears for the *Atlanta* and *Hartford*.

Drawings for new propeller shafts for the *Marietta*, *Wilmington* and *Helena*.

In addition to the above, designs have been made for the layout of new steam-engineering shops at the navy yards, New York, Mare Island and Port Royal, and much detail regarding the interior arrangement of these gone into.

Attention has been given to the collecting of, and tabulating for future use, valuable data from the designs and weight sheets, and also from indicator diagrams, study being constantly given to improvements in general design based upon valuable and exact information.

The questions of best cylinder ratios for multiple-expansion engines, economical arrangements for using superheated steam, practical limit for true economy in forced draft, reduction of cost of horsepower of auxiliary machinery by improved design, efficient feed-water heating by exhaust steam, and the still further improvement in the screw propeller, tending to bring it nearer the point of highest efficiency, are among those most important in the work of this branch of the Bureau.

There is much work connected with the drafting room and the clerical work of the Bureau which can not be kept up to a de-

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sirable state of completion, especially in connection with tabulating data. These, if properly arranged, are of utmost value to the Bureau and to the Department, and an increase both in draftsmen and in the clerical force of the Bureau being highly desirable, your attention to the matter and favorable recommendations to Congress are requested.

INSPECTION OF MATERIAL.

The importance of this work as alluded to above in this report can scarcely be overrated, and its continuance by engineering experts should be a matter unhesitatingly followed. The following detailed statement regarding the work under this head during the year is a valuable record, and illustrates more graphically than anything else could the broad field covered by the many builders in placing orders for material and the extensive nature of the inspection duty. While the statement shows the total amount of material accepted, the fact must not be lost sight of that a very large percentage of material is necessarily rejected at the works, and that percentage should be added to fully represent the actual labor involved in this particular duty.

This Bureau has now permanent inspection headquarters, in charge of commissioned officers, at the following places:

1. Homestead Steel Works, Munhall, Pa., one officer, with four civilian assistant inspectors and one copyist, who do all work at Pittsburg, Pa., and suburbs, Ellwood, Pa., Greenville, Pa., Johnstown, Pa., Washington, Pa., Latrobe, Pa., Cleveland, Ohio, Shelby, Ohio, Youngstown, Ohio, and Buffalo, N. Y.

2. The Midvale Steel Company's works, Nicetown, Philadelphia, Pa., one officer, with two civilian assistant inspectors, who do the work at Philadelphia, Pa., and suburbs, Conshohocken, Pa., Coatesville, Pa., Parkesburg, Pa., Phœnixville, Pa., and Pottstown, Pa.

3. The Bethlehem Steel Company, South Bethlehem, Pa., one officer, with two civilian assistant inspectors and one copyist, who do the work at Bethlehem, Pa., and High Bridge, N. J.

The laboratory at this place, built by the Bethlehem Steel Company for the use of this Bureau, is used exclusively for the

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work of the Navy Department, and is provided with chemicals and apparatus by the Department. One assistant inspector, aided by a messenger boy, does here all the chemical work coming under its cognizance.

4. The American Steel Casting Company, Thurlow, Pa., one officer, with one civilian assistant inspector, does all the work at Thurlow, Pa., Chester, Pa., and Wilmington, Del.

5. The Pennsylvania Steel Company, Steelton, Pa., one officer, with one civilian assistant inspector, does the work at Steelton, Pa., Harrisburg, Pa., Danville, Pa., Reading, Pa., Middletown, Pa., Athens, Pa., Syracuse, N. Y., and Elmira, N. Y.

6. The Continental Iron Works, Brooklyn, N. Y., one officer does the work in Greater New York, Hoboken, N. J., Newark, N. J., Harrison, N. J., and Whitestone, Long Island.

7. The Pope Tube Company, Hartford, Conn., one officer, with one civilian assistant inspector, does the work at Hartford, Conn., Waterbury, Conn., Bridgeport, Conn., Ansonia, Conn., Torrington, Conn., New London, Conn., Providence, R. I., Boston, Mass., Taunton, Mass., Canton Junction, Mass., and New Bedford, Mass.

8. Masonic Temple, Chicago, Ill., one officer inspects at Chicago, Ill., Milwaukee, Wis., and St. Paul, Minn.

The officers and civilian assistants, under the cognizance of this Bureau, tested, inspected and shipped for the Bureau of Yards and Docks, 4,679,296 pounds of structural material, plate, angles, shapes and rivets, also the structural work of putting together this material; for the Bureau of Equipment, 503,233 pounds of structural material, anchors and their fittings; for the Bureau of Construction and Repair, 1,978 pounds of castings; for the Fish Commission, 102,864 pounds of boiler material, and for work coming under its own cognizance, 5,299,800 pounds of steel forgings, steel castings, steel plates, boiler bracing, steel and iron rivets, steel and iron bolts and nuts, steel and iron boiler tubes, steel and iron steam and water pipe, condenser tubes, brass and copper pipe and sheets, finished corrugated furnaces, steam drums for tubular boilers, and other finished articles in brass, copper, steel and iron, the grand total successfully passing inspection being 10,587,175 pounds.

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The work was distributed among the following companies in cities and towns reaching from Boston, Mass., to St. Paul, Minn.:

American Steel Casting Company, 230,560 pounds of steel castings, of which 135,549 pounds was for the Bureau of Equipment, the remaining material being used in the construction of the machinery of the *Dahlgren*, *Craven*, *Illinois*, *Wilmington*, *Stringham*, *Tingey*, *Maine*, *Ohio*, *Wyoming*, *Hopkins*, *Hull* and *Alabama*.

The Auburn Bolt and Nut Company, 25,427 pounds of seamless drawn tubes for the *Ericsson*.

Atha and Illingworth Company, 119,643 pounds of steel castings, blooms, bars and forgings for the *Dahlgren*, *Craven*, *Blakely*, *De Long*, *Lawrence*, *Macdonough*, *Shubrick*, *Stockton*, *Thornton*, *Connecticut*, *Bagley*, *Bailey*, *Biddle*, *Dale* and *Decatur*, as well as for the New York yard.

American Tube Works, 258,262 pounds of condenser tubes, brass and copper pipe for the *Stringham*, *Yorktown*, *Florida*, *Dale*, *Decatur*, *Blakely* and *De Long*; also for repairs to vessels, naval supply fund, and for general use at the navy yards, New York and Mare Island.

Allison Manufacturing Company, 296,019 pounds charcoal-iron boiler tubes for the *Puritan* and for the New York Navy Yard.

American Iron and Tube Company, 77,232 pounds iron pipe for naval-supply fund, navy yard, New York.

Bethlehem Steel Company, 236,120 pounds nickel-steel forgings, of which 693 pounds was for the Bureau of Construction and Repair, the remainder being used in the construction of the machinery of the *Stringham*, *Foote*, *Rodgers*, *Dahlgren*, *Craven*, *Bailey*, *Goldsborough*, *Blakely*, *De Long*, *Shubrick*, *Stockton*, *Thornton*, *Paul Jones*, *Perry*, *Preble*, *Maine*, *Dale* and *Decatur*, and for repairs to the *Newark* and *Wheeling*, and for the New York Navy Yard.

Benedict and Burnham Manufacturing Company, 150,977 pounds condenser tubes, brass and copper pipe for the *Bailey*, *Nicholson*, *O'Brien* and *Wilkes*, and for repairs to the *Indiana* and *Iowa*, and for the naval-supply fund, navy yard, New York.

Bridgeport Brass Company, 95,849 pounds condenser tubes,

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brass and copper pipe for *Tingey*, *Paul Jones*, *Preble*, *Wisconsin* and *Wyoming*, and for the naval-supply fund at the navy yard, New York.

Carbon Steel Company, 514,432 pounds steel boiler plate, of which 3,990 pounds was for the Bureau of Yards and Docks, the remainder being used in the construction of the boilers of the *Bailey*, *Nicholson*, *O'Brien*, *Shubrick*. *Stockton*, *Thornton*, *Hull*, *Paul Jones*, *Hopkins*, *Dale*, *Decatur*, *Lawrence*, *Blakely*, *De Long*, *Bainbridge*, *Barry*, *Chauncey*, *Connecticut*, *Macdonough* and *Florida*, and for repairs to the *Alert*, and for navy yard, Boston, Mass.

Continental Iron Works, welded steam and water drums for water-tube boilers and corrugated furnaces, the weight of which has been once taken note of at the steel works.

Coe Brass Manufacturing Company, 77,473 pounds condenser tubes, brass and copper pipe for the *Worden*, *Truxtun* and *Whipple*, and for repairs to the *Indiana* and *Columbia*.

Central Iron and Steel Company, 97,630 pounds steel plates for the Bureau of Yards and Docks.

Cambria Steel Company, 54,100 pounds steel plate and shapes for the Bureau of Yards and Docks.

Homestead Steel Works, 1,015,730 pounds steel plate, angles and shapes, of which 1,004,300 pounds was for the Bureau of Yards and Docks, the remainder being for the *Illinois* and repairs to the *Monadnock*.

Dauphin Bridge Company, 213,589 pounds structural material for the Bureau of Yards and Docks.

Elmira Bridge Company, 312,511 pounds structural material for the Bureau of Yards and Docks.

Franklin Machine Company, 7,283 pounds of iron castings for the *Shubrick*.

Holmes, Booth & Hayden, 52,896 pounds brass and copper pipe for repairs to the *Monadnock*, and for the navy yard, Norfolk, Va.

Hussey, C. G., & Co., 4,251 pounds Muntz metal plates for *Dale* and *Decatur*.

Lower Union Mills, 370,426 pounds steel plates, angles and shapes, of which 161,763 pounds was for the Bureau of Yards

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and Docks and 195,553 pounds for the Bureau of Equipment, the remainder being for repairs to the *Indiana*.

Latrobe Steel Works, 2,181 pounds steel-pipe flanges for *Dahlgren*, *Craven* and *Stringham*.

Lukens Iron and Steel Company, 443,294 pounds steel plate, of which 70,830 pounds was for the Fish Commission, 260,239 pounds for the Bureau of Yards and Docks, and the remainder for repairs to the *Pontiac*.

Midvale Steel Company, 139,364 pounds steel forgings, of which 91,030 pounds was for the Bureau of Equipment, 1,285 pounds for the Bureau of Construction and Repair, the remainder being nickel-steel forgings, to be used in the construction of the machinery of the *Hopkins*, *Hull*, *Nicholson*, *O'Brien*, *Bainbridge* and *Barry*, and for repairs to the *Cushing*.

National Tube Works, 586,504 pounds lap-welded and seamless-drawn iron and steel boiler tubes and pipes, of which 16,864 pounds was for the Fish Commission, the remainder being used in the construction of the boilers of the *Stringham*, *Dahlgren*, *Craven*, *Goldsborough*, *Dale*, *Decatur*, *Perry*, *Paul Jones*, *Preble*, *Shubrick*, *Stockton*, *Truxtun*, *Whipple*, *Worden*, *Thornton*, *Blakely*, *De Long*, *Tingey*, *Bainbridge*, *Barry*, *Chauncey*, *Hopkins* and *Hull*, and for repairs to the *Vesuvius*, *Massachusetts*, *Oregon*, *Texas*, *Katahdin* and *Iris* and for the Norfolk and New-York navy yards.

New Bedford Copper Company, 6,732 pounds of Muntz metal sheets for the *Truxtun*, *Whipple* and *Worden*.

The Penn Steel Casting and Machine Company, 44,713 pounds steel castings, of which 1,563 pounds was for the Bureau of Equipment, the remainder being used in the construction of machinery of the *Stringham*, *Kearsarge*, *Kentucky*, *Goldsborough*, *Tingey*, *Bailey*, *Florida*, *Nicholson*, *O'Brien* and *Connecticut*.

Pacific Rolling Mills, 1,277 pounds steel plates for the *Wisconsin*.

Parkersburg Iron Company, 508,412 pounds skelp for boiler tubes for the *Puritan* and other vessels.

Pope Tube Company, 288,915 pounds seamless-drawn steel

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tubes for the *Shubrick*, *Stockton*, *Tingey*, *Hopkins*, *Hull*, *Thornton*, *Dale*, *Decatur*, *Chauncey*, *Bainbridge* and *Barry*.

Park Brothers & Company, 57,110 pounds steel boiler plates for the Bureau of Equipment.

Phœnix Iron Company, 587,948 pounds steel angles and shapes, of which 453,398 pounds was for the Bureau of Yards and Docks, 570 pounds for the Fish Commission, and the remainder used in the construction of the machinery of the *Maine*, *Hopkins*, *Hull*, *Lawrence*, *Macdonough* and *Tingey*.

Pittsburg Bridge Company, 218,640 pounds structural steel material for the Bureau of Yards and Docks.

Pencoyd Iron Company, 4,113 pounds steel angles and shapes, of which 1,777 pounds was for the Bureau of Yards and Docks, the remainder being for the *Nicholson* and *O'Brien*.

Randolph & Clowes, 93,074 pounds condenser tubes, brass and copper pipe for repairs to the *Indiana* and *Massachusetts* and for the naval-supply fund at the New York and Mare Island navy yards.

Revere Copper Company, 21,111 pounds Muntz metal and copper sheets for the *Decatur*, *Stockton*, *Shubrick*, *Dale*, *Thornton*, *Missouri* and *Arkansas*.

Shelby Steel Tube Company, 1,188,068 pounds seamless-drawn steel tubes for the *Dupont*, *Porter*, *Foote*, *Rodgers*, *McKee*, *Preble*, *O'Brien*, *Nicholson*, *Perry*, *Blakely*, *Stockton*, *Shubrick*, *Thornton*, *Stewart*, *Paul Jones*, *Wilkes* and *De Long*, and for repairs to the *Winslow*, *Nashville*, *Iowa*, *Brooklyn*, *Bennington*, *Minneapolis*, *Texas*, *Ericsson*, *Alert*, *Scorpion* and *Bancroft*, and for the New York yard.

Sizer Steam Forge Company, 2,400 pounds nickel-steel forgings for tugboat No. 7, the *Pawtucket*.

Sternberg & Son, J. H., 29,489 pounds rivets, bolts and nuts, of which 14,600 pounds was for the Fish Commission, the remainder being used in the *O'Brien*, *Nicholson*, *Shubrick*, *Stockton*, *Thornton*, *Dahlgren*, *Craven*, *Dale*, *Decatur*, *Bagley*, *Barney*, *Biddle* and *Tingey*, and for the naval-supply fund at the New York and Boston navy yards.

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Severance, Samuel, 7,995 pounds rivets for the Bureau of Yards and Docks.

Tyler Tube Company, 89,300 pounds charcoal-iron boiler tubes for the *Illinois*.

Taylor Iron and Steel Company, 1,921 pounds steel castings for the *Shubrick*, *Stockton* and *Thornton*.

Taylor, Lewis & Co., 6,054 pounds steel plates for the *Stringham*.

Taunton Copper Company, 3,946 pounds copper sheets for the *Connecticut*, *Barney* and *Biddle*.

Union Bridge Company, 796,790 pounds structural material for the Bureau of Yards and Docks.

Upper Union Mills, 1,105,755 pounds steel plates, angles and shapes, of which 1,103,797 pounds was for the Bureau of Yards and Docks and the remainder for the *Illinois*.

Worth Brothers Company, 132,713 pounds steel boiler plates for the *Paul Jones*, *Perry* and *Preble*, and for repairs to the *Indiana* and *Terror*.

The Alan Wood Company, American Steam Gauge Company, Deoxidized Bronze and White Metal Company, Pratt & Cady, and The Star Brass Company furnished finished articles amounting to 1,815 pounds in weight.

The Bureau finds that there has been great improvement during the year in the manufacture of high-grade engine forgings. The two companies who have taken contracts for these forgings, which are of nickel-steel, oil tempered and annealed, or of nickel-steel annealed, have been very successful in meeting all the requirements of the specifications, but in consequence of the rush of trades orders have not turned out as rapidly as was expected for the new battleships, monitors, torpedo boats and torpedo-boat destroyers authorized by the act of Congress approved May 4, 1898, but from this time on their production will be more rapid, all the difficulties in their manufacture having been practically overcome.

The manufacturers of seamless-drawn steel pipe have increased the size and power of their machinery so that steam and water pipe up to 7 inches in diameter can now be made in long lengths

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and 9-inch pipe in lengths up to 9 feet. The flanges for these pipes are either solid, welded on, rolled on, or riveted on; but there is a fair prospect that the manufacturers will soon be able to turn out these sizes with flanges made by upsetting the end of the pipe, spreading these upset ends, and then forming them into flanges, all of which work will be done at a single heat. This can now be successfully done in cases of the smaller sizes, and the results are highly satisfactory in both appearance and strength.

There has been some discussion as to what is meant by "solid drawn" tubes. With this Bureau this term only includes tubes drawn through dies from the solid ingot, and does not include lap-welded sections drawn down to smaller-sized tubes. The latter may present an excellent surface, but there is always a possibility of a weld being started in the process of drawing, and yet of such a slight nature as only to show as a defect after being put in service.

ELECTRICALLY-DRIVEN AUXILIARIES.

For some time past—in fact, ever since the successful use of electric motors for general power purposes on shore—the Bureau has been carefully investigating their adaptability to the driving of the numerous auxiliary engines on board ship, and, in view of the conclusion that the electric drive of the auxiliaries would not, under existing conditions, be so satisfactory and economical, on the whole, as the steam drive, believes it would be of interest to state the reasons for this conclusion.

This is the more appropriate because in some quarters the fact that electric motors are extensively used on shore has led to the belief that they would be equally successful on board ship. The Bureau has planned to use electric motors exclusively in its new plant at the Brooklyn Navy Yard, and it will be readily appreciated, therefore, that their non-use on board ship is for very good reasons.

The advantages claimed for electric motors over small steam engines on board ship may be classed as greater ease of operation, avoidance of heat, which accompanies the use of steam pipes in living places, and much greater economy. Against these, how-

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ever, are to be put the much greater weight of the necessary electric outfit, the greater delicacy of the type of electric motors ordinarily used, the lack of ready adaptability to the various conditions of service, a general denial of the claims for economy as ordinarily presented, and the increase in the amount of space required below the protective deck for the installation of the necessary dynamo rooms, this space being necessarily taken from coal bunkers.

On board ship, where excess of weight is so carefully guarded against, it would certainly be very unwise to adopt a change of motive power involving great increase in weight, unless the advantages gained are very material. It must always be remembered that, speaking generally, on board ship the use of an electric motor involves a total weight for the motive power at least three times that of the motor itself, because there is always the generator and its driving engine, besides the motors supplied by them; or, in other words, the electric drive of an auxiliary will weigh at least three times as much as the steam drive, assuming the motor to weigh no more than the engine it displaces, although usually it does weigh more. The answer which would be made to this is, of course, very familiar to anybody who has studied the problem, viz: that the auxiliaries are not all in use at one time, and that therefore the generator capacity required is considerably less than the total motor capacity. This is another case where a statement which may be true elsewhere is not true for the circumstances on board ship. Our naval machinery has to be designed so that in time of action everything can be ready for use, and, as a matter of fact, a very little study of the question will show that it not only may but almost certainly would happen that every auxiliary on the ship, except the capstan engine and some of the boat winches, would be used simultaneously. Therefore this statement with regard to the generator capacity does not hold on board ship.

Another statement to which very emphatic objection must be entered is in respect to the enormous gain in economy claimed for the electric drive of the auxiliaries, which is obtained by tak-

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ing the highest figure for the efficiency of the generator and motor and also the most economical steam engine, and by comparing these results with the uneconomical form of steam cylinders which, for very good reasons, have until recently ordinarily been used with the steam-driven auxiliaries. If the electric generator was of relatively large size and the motors worked always at their most economical speed and load there might be some justification for this claim; but, as a matter of fact, the very circumstances under which the auxiliaries on board ship are worked require a very wide range of speed and power, and I believe that electric experts admit that electric motors as at present designed when run under these conditions are by no means economical, so that, without considering the economy of the engine driving the electric generator, the economy of motor-driven auxiliaries at speeds differing materially from the most economical would be widely different from those which are set forth by the advocates of their universal use on board ship. The natural result of the foregoing is that, with the widely varying speeds of the auxiliary machinery, there is required at the generator the development of an almost constant power which is very near the maximum, and which depends only upon the number of auxiliaries in use.

I wish to emphasize the point that the objection to using electric motors for driving the auxiliaries on board ship is not an objection to the use of electric motors per se, but to installing them in a location for which they are not adapted and where their good features can not be utilized. What has led to the wide use of electric motors on shore is not only the absence of heat, cleanliness and ease of installation and operation, but above all the simplicity of the transmission of power from a central station to a distance. Now the great majority of the auxiliaries on board ship are so near the boilers that less piping is involved in a direct steam drive than in an electric drive from dynamos necessarily at some distance from the boilers.

The ease of transmitting power to a distance over a wire, as compared with great lengths of steam piping, gives the electric drive a very attractive side, even for distances no greater

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than the maximum ones on board ship, so that we should naturally expect to find electrically-driven capstans and steering engines. These two auxiliaries are not under this Bureau, but are the ones requiring long and objectionable steam pipes through the living spaces. Here, however, another point has been made by some who are very anxious to use motors elsewhere, viz: that for the service in these cases motors are not sufficiently reliable. Naturally a system involving four parts, each liable to break down, is more delicate than one involving but two of these parts. With a steam drive there are the boilers and the steam engine driving the auxiliaries. In the electric drive we have the boilers, the steam engines, and also the electric generators and motors. It is merely a detail whether the steam engines operate the auxiliaries directly or whether a smaller number of them, having a greater power in each engine, operate electric dynamos. Personally I should think, however, that if motors are considered sufficiently reliable to drive feed pumps and air pumps on shipboard, for which they are not well adapted, they would be reliable for these other two cases noted, which they fit so well otherwise. The absurdity of an electric drive of auxiliary machinery on board ship situated closer to the main engines than the engines driving the dynamos becomes all the more apparent when contrasted with the steam drive for auxiliaries situated in the very extreme ends of the ship.

The fact is that within what are ordinarily called the "machinery compartments of the ship" the leading of the necessary steam and exhaust pipes for auxiliaries does not interfere with anybody's comfort nor does it raise the temperature unduly, and the distances are so short as to make the lead of piping very easy. Steam auxiliaries answer admirably the demands which come upon them at all speeds within their capacity, and the only possible objection which can be urged against them is that the simple forms usually employed for reliability are not so economical as the more elaborate ones which can be used elsewhere. They are far superior to electric motors on the score of adaptation to the service to be performed, and also far better for naval use on the score of weight. On the score of economy, we have shown

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above that the claims ordinarily made for the electric drive are not tenable, except under special conditions, and it is further to be said for the steam-driven auxiliaries that at the times when economy is of the greatest importance when making long sea trips only a small part of the total auxiliary capacity is used, so that even if the saving by the use of electricity was what is claimed by the most enthusiastic electrical agents the aggregate amount of fuel saved would be comparatively insignificant and considerably less than the reduction in bunker capacity necessarily incident in a ship of a given size to the use of the electric drive.

It must also be noted that all the published statements of the superior economy of electrically-operated auxiliaries are based on steam auxiliaries where every steam cylinder was of the least economical kind, and where, for good reasons, well-known measures of economy had not been installed. An inspection of the Bureau's recent designs will show that by the use of compound engines as motors, feed heaters for the exhaust, the use of the exhaust steam from the auxiliaries in the receivers of the main engines, and other economical devices, the expenditure of steam in the auxiliaries is brought much below that of the old simple engines, and indeed below that of the electric drive except under very favorable conditions, while avoiding the increased complication and weight which necessarily accompany electrically-driven auxiliaries on board ship. I may be permitted to call attention in this connection to the fact that those designers abroad who have the most extended experience are working on this problem of the economy of auxiliaries along the same lines that the Bureau has been following. Although the statement is very often made that the electric drive of the auxiliaries is being rapidly adopted in all foreign navies, this is far from accurate. It is being tried on some ships in some navies, but is as yet entirely in the experimental stage. These experiments have been carried quite as far in our Navy as in any other. I think I may be pardoned for saying that those who are most insistent on the electric drive are not at all conversant with the conditions obtaining on board ship, while those of us who have spent a

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lifetime in the care and design of naval machinery may fairly claim that we know something about what is needed. It is perfectly safe to say that when electric machinery can be used more advantageouly than steam for driving ships' auxiliaries the change will be made very promptly. Knowing, as they do, that as at present designed electric machinery, however good elsewhere, is not yet adapted to driving the auxiliaries on board ship, the Bureau chiefs would be incompetent if they yielded to the craze for new things and made a change which would result in increase of weight and complication, lack of economy, dissatisfaction and decreased efficiency of the fleet.

In this connection I desire to submit the following facts and calculations:

On the battleship *Alabama* the space required for electric motors, where used, is approximately the same as that required for steam engines to do the same work. The space required for the wiring, etc., is less than that necessary for steam piping, had that been used. The space required for the generating sets is 10,140 cubic feet. The capacity of these generating sets is 256 kilowatts total. If all the auxiliary machinery on board this ship were operated by electricity, and if the space required for the electric generators were increased in the ratio of the increase of necessary capacity in the generating room, the space that would be required in the generating rooms would be 50,700 cubic feet for a capacity of 1,280 kilowatts. Consequent upon the extension of the use of electricity would be an increase in the total weight of the machinery equal to from 150 to 250 tons as a minimum. This loss in weight is as much as the gain following the use of water-tube boilers. The increased space occupied by the larger generating rooms would accommodate 900 tons of coal, or 3,600 horsepower could be added to the power of the propelling engines, giving the ship in the first instance 45 per cent. greater coal endurance, or in the second instance 1.5 knots increase in speed.

The foregoing figures as to the space required for the installation of larger generating sets are undoubtedly excessive, but they are based upon the present practice. It seems to me that at the

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best we would at present have to pay an excessive price for electricity.

This weight and space required would be very much less if the size of the electric generating units could be largely increased without loss to the efficiency of the ship. At present, however, it is necessary for the efficient operation of the turret-turning machinery and of the ammunition hoists that small units be used, for these purposes at least. Probably when the designers of electrical machinery for naval use give as much attention to the development of designs to suit naval conditions as they have already done in commercial work this necessity will be overcome.

I consider that the turbine engine has a distinct field as an electric generating engine, especially on shipboard. When the design of naval electrical machinery is sufficiently advanced to justify the use of large units the advantages of turbine engines will cause a great saving in weight and space.

The operation of electrical machinery is purely mechanical. That this may be done efficiently requires good mechanical ability at the generating engines. Electric difficulties and casualties are almost always questions of mechanical engineering. I know that it would conduce to the efficiency of the service, to the feasibility of a more extended use of electricity, and to an increase in the life of electrical apparatus if the electric generating plant were placed in charge of this Bureau. I therefore recommend that this change be authorized. I desire to call your attention to the fact that it is almost the universal commercial practice to place electric generating plants in the charge of mechanical engineers.

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EXPERIMENTS AND TESTS.

Under this heading the report gives:

A test of a Babcock & Wilcox boiler for the *Alert.*

A test of the machinery of the *Pennsylvania.*

A test of the machinery of the *Alexander McDougal.*

A test of a Niclausse boiler at Cramps.

A test of the evaporating plant of the *Iris.*

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Of the above the first two tests were separately written up for the JOURNAL, and have been published in former numbers of this volume. The last two tests we here reprint as valuable data.

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TESTS OF A NICLAUSSE BOILER AT THE WORKS OF WILLIAM CRAMP & SONS, PHILADELPHIA, PA.

A series of tests was made May 2 to 6, 1899, by a board composed of Lieutenants H. Hall, W. W. White and E. Theiss, United States Navy, on a Niclausse water-tubular boiler installed as a part of the dry-dock power plant at the establishment of the William Cramp & Sons Ship and Engine Building Works, Philadelphia, to determine the economy of the boiler at several different rates of coal consumption, and the economical effect, if any, following the operation of a heater located in the escaping gases, and by which means, when in use, the air entering the ash pit was considerably raised in temperature.

The boiler tested was of a stationary form and setting, with the following principal dimensions:

Diameter of drum, inches	36
Length of drum, inches	72
Number of malleable iron headers	7
Number of steam generating tubes connected to each header	18
Total number of steam generating tubes	126
Effective length of steam generating tubes, feet	$8\frac{1}{3}$
Diameter of steam generating tubes, inches	$3\frac{13}{16}$
Number of inner circulating tubes	126
Diameter of inner circulating tubes, inches	2
Thickness (sheet iron) of inner circulating tubes, B.W.G.	20
Tube heating surface, square feet	1,081.5
Heating surface in headers, square feet	10.5
Total heating surface, square feet	1,092
Width of grate, feet and inches	5- 5
Length of grate, feet and inches	3-$10\frac{1}{2}$
Grate surface, square feet	21
Air space in grate, per cent	50
Ratio of H.S. to G.S.	52 to 1
Boiler setting, 8 feet 4 inches wide by 10 feet long by 14 feet 7 inches high.	
Diameter of smoke pipe, feet	4
Height of smoke pipe, feet	60

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The original grate was shortened from 5 feet 2 inches to 3 feet 10½ inches, reducing the grate surface from 28 to 21 square feet. The ratio of H.S. to G.S. was by this change increased from 39 : 1 to 52 : 1.

A belt-driven fan blower had been installed in a shed adjoining the boiler house for forcing the draft. This fan discharged the air through a duct of 17 inches diameter, and it was admitted to the ash pit through an opening controlled by a damper valve; also through a separate opening controlled by a damper valve and through interstices between the fire-brick lining of the furnace at one side, near the front, above the grate. It was claimed that the introduction of air above the grate led to more complete combustion, but no noticeable change was produced by the opening or closing of the air-admission valve.

The air duct was so arranged that the air on its way to the ash pit could be made to pass along the tubes of a heater, located at the bottom of the flue at back of boiler, or so that it could be passed directly to the ash pit, through a by-pass duct, sliding blank flanges being arranged for this purpose.

The air heater consisted of a nest of vertical tubes expanded at both ends into horizontal tube plates. The gases of combustion passed through the tubes, and the air to be heated passed among them, entering at one side of the boiler and leaving at the other.

The following are the principal dimensions of the forced-draft apparatus and the air heater:

Fan, 3 feet 7 inches diameter by 19¾ inches wide; 5 vanes.	
Outlet, inches	21½ by 21½
Pulley, diameter, inches	10
Engine, inches	8 by 8
Flywheel pulley, diameter, inches	36
Heater:	
Number of tubes	102
Length of tubes, feet and inches	3– 4½
Diameter of tubes, inches	3
Thickness of tubes, B.W.G	No. 14
Area through tubes, square feet	4.96
Area between tubes, square feet	3.14
Air duct, diameter, inches	17
Area of inlet above grate, square foot	0.36

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The instruments used were not calibrated by the board, but were of standard make, and no doubt exists as to their substantial accuracy. The pyrometer used for recording temperatures in the flue was of the metallic dial variety; its readings are supplemented by a record of metals melted.

The cooling tank used during the first three tests for obtaining the quality of steam by the Carpenter separating calorimeter was too small to give reliable results; for the last two tests a more capacious tank was secured, but the results as to quality of steam did not differ materially from those of the previous tests; the steam was in all cases practically dry. A portable Orsat apparatus was used for making the fuel gas analyses, which analyses were made by the chemist of the firm at his laboratory. The samples were taken with the greatest possible care.

The steam pressure was kept as nearly constant as possible by the manipulation of a stop valve allowing of the escape of steam to the atmosphere. During a part of the tests the boiler experimented on was used for furnishing steam to the dry-dock pumping machinery, but the regulation of pressure proceeded just as smoothly and in the same manner as when steam was permitted to escape into the air.

The feed pump had been mounted near the boiler, with all pipe connections in plain sight, and the water level was kept as nearly as possible at the uniform height of 2 inches in the gage glass.

The firing was done by the same experienced man during all the tests. This man fired at frequent intervals and little at a time, keeping the fires as thin as possible. The flue gas analysis shows at all times a large percentage of free oxygen, and a small percentage, relatively, of carbonic dioxide, showing that much surplus air passed through the grate. It is noticeable, however, that the analysis of flue gas taken off with fires purposely carried heavy (see analysis of gases drawn off at 2.55 P. M., May 5, test No. 4) also shows a large excess of air. Some of this apparent excess is accounted for by leaks in the brick setting, though they are totally inadequate to account for more than a small percentage. The relief fireman did not have the experience of the regu-

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lar hand, and his taking hold was always signalized by a decided jump in the temperature of uptake gases. Also toward the end of each test, when the firing became less careful, a similar jump is to be recorded. In fact, the boiler, as is to be expected from the straightway course of the gases, is extremely sensitive to variations in firing with consequent variations in the uptake temperatures.

Five tests were undertaken on five consecutive days, May 2 to 6, 1899:

The first test was undertaken using cold ash-pit draft, burning as nearly as possible 30 pounds of coal per square foot of grate surface per hour. The table shows that 27.45 pounds were burned.

The second test was run under as nearly as possible the same conditions as the first, the only difference being that the air was passed through the heater on its way to the furnace. It was difficult to regulate the blower so as to obtain the desired uniform rate of combustion. The day preceding had been warm and murky, and the day of the second trial opened in the same way. In the course of the day, however, the weather cleared and a fresh breeze sprang up, increasing in strength, so that the blower, started at 500 revolutions, had to be gradually slowed to 330.

The coal burned per hour per square foot of grate during this test was 27.52 pounds, practically the same as on the day preceding. The evaporation per pound of coal under actual conditions rose from 7.72 to 7.84 for a difference in temperature of the air entering the ash pit of (189.1—106.4)=82.72 for the two days, with a corresponding difference in the temperature of uptake gases at base of chimney of (457—341.5)=115.5 degrees.

The third test was undertaken to determine the performance of the boiler under natural draft, burning as much coal as possible. The weather conditions were similar to those obtaining on the previous day, and a brisk fire was easily maintained, so that the consumption was not much below what it would have been with ash-pit draft, being 24.62 pounds per square foot of grate surface per hour.

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The fourth test was intended to demonstrate the performance of the boiler under easy firing, natural draft, and 14.74 pounds of coal were burned per square foot of grate per hour.

The fifth test was undertaken to demonstrate the performance of the boiler under what may be assumed to be maximum forced-draft conditions on naval vessels other than torpedo boats and destroyers. The consumption reached the figure of 46.76 pounds per square foot of grate per hour. The blower delivered into the closed ash pit, and the air heater was in use. During this test, in the course of which the air pressure in the furnace averaged slightly above atmospheric pressure, the leaks in the brick setting manifested themselves by the escape of smoke, which hung over the top of boiler and made reading of the steam calorimeter difficult. One of the furnace doors became badly warped during this test, not having been a good fit at the start, and some loss occurred due to the loss of flame from this furnace mouth. The leakage was imperfectly stopped by wrapping the door with asbestos sheet.

The coal used in all tests was Clearfield (Pa.) coal, Atlantic brand. A quantity of this coal had been stored close to hand in a shed, and the coal used in tests Nos. 1–4 was taken from this supply. For test No. 5 the coal was carted from another part of the yard. The following proximate analyses of the coal and ash were made by the firm's chemist, Mr. Jesse Jones:

COAL USED IN TEST OF NICLAUSSE BOILER.

Number.	Run of—	Moisture.	Volatile.	Fixed.	Ash.	Color of ash.
3,381	May 2	0.45	18.85	73.20	7.50	Grayish-white.
3,390	May 3	.55	18.45	74.65	6.35	Grayish-white.
3,416	May 4	.80	16.05	73.00	10.15	Gray.
3,421	May 5	.95	17.55	75.10	6.40	Gray.
3,432	May 6	.80	18.75	73.50	6.95	Gray.

ASH FROM ABOVE.

Number.	Run of—	Moisture.	Volatile.	Fixed.	Ash.
3,382	May 2	0.10	2.45	12.95	84.50
3,391	May 3	.05	2.85	15.60	81.50
3,417	May 4	.10	2.40	21.05	76.45
3,422	May 5	.05	2.90	16.25	80.80
3,433	May 6	.10	3.10	10.50	86.30

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SUMMARY OF TESTS OF A NICLAUSSE BOILER AT WILLIAM CRAMP & SONS' SHIPYARD, MAY 2-6, 1899.

Number of trial	1	2	3	4	5
Date of trial, 1899	May 2.	May 3.	May 4.	May 5.	May 6.
Duration of trial.....hours	6	6	10	10	6
Kind of start	Flying.	Flying.	Standard.	Standard.	Flying.
Average Pressures.					
Barometer.....inches	29.95	29.99	30.16	30.15	30.24
Steam pressure in boiler by gage.....lbs.	121.9	124.7	122.3	122.8	124.9
Draft in blower duct to ash pit..ins. water	.26	.19	*	*	.71
Draft in ash pit.....do.	.32	.22	*	*	.86
Draft in furnace.....do.	.08	.09	.22	.16	.08
Draft in flue behind boiler.....do.	.11	.14	.26	.18	.13
Draft at base of smoke pipe.....do.	.37	.43	.40	.34	.50
Revolutions of blower.....per minute	343	423	...	...	781.
Average Temperatures.					
External air.....degrees Fahrenheit	84.6	70.7	62	69.4	69
Fire room.....do.	98.2	80.4	79.8	85	96.6
Feed water entering boiler.....do.	64.8	64.9	64.3	65.2	65.2
Air before entering heater.....do.	...	83.7	...	...	86.2
Air entering ash pit.....do.	106.4	189.1	...	...	219.9
Flue gases before entering heater....do.	...	525	464	389	794
Flue gases after passing heater.....do.	457	341.5	...	...	592.5
Average Flue Gas Analysis.					
Carbon dioxide.....per cent	6.18	5.07	4.95	6.74	7.10
Oxygen.....do.	11.58	13.73	13.63	11.62	9.60
Carbonic oxide.....do.	.94	.62	.77	.53	.90
Nitrogen.....do.	81.30	80.58	80.65	81.11	82.40
Fuel.					
Kind of coal	†	†	†	†	†
Wood used in lighting fire.....pounds	...	...	300	300	...
Coal as fired ‡.....do.	3,459	3,468	5,170	3,095	5,891.5
Moisture in coal.....per cent	3	2.69	3.03	3.38	1.25
Dry coal consumed.....pounds	3,355.2	3,374.7	5,013	2,990.4	5,818
Ash and refuse.....do.	236	244	335	233	340
Combustible consumed.....do.	3,119.2	3,130.7	4,678	2,767.4	5,478
Refuse in dry coal.....per cent	7.03	7.23	6.68	7.46	5.84
Rates of Combustion per Hour.					
Coal consumed.....pounds	576.5	578	517	309.5	981.9
Dry coal consumed.....do.	559.2	562.5	501.3	299	969.7
Combustible consumed.....do.	519.9	521.8	467.8	276.7	913
Coal consumed per square foot of grate surface.....do.	27.45	27.52	24.62	14.74	46.76
Dry coal consumed per square foot of grate surface.....do.	26.63	26.79	23.87	14.24	46.18
Combustible consumed per square foot of grate surface.....do.	24.76	24.85	22.28	13.18	43.48
Coal consumed per square foot of water-heating surface.....do.	.528	.529	.473	.283	.899

* Natural draft.
† Clearfield Bituminous-Atlantic brand.
‡ Including equivalent of wood used in lighting fires.

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SUMMARY OF TESTS OF A NICLAUSSE BOILER—Continued.

Number of trial	1	2	3	4	5
Dry coal consumed per square foot of water-heating surface.....pounds..	.512	.515	.459	.274	.888
Combustible consumed per square foot of water-heating surface.....do..	.476	.478	.428	.253	.836
QUALITY OF STEAM.					
Quality of steam (dry steam = unity)....	.999	.999	.999	.998	.993
WATER.					
Total fed to boiler and apparently evaporated.....pounds..	26,688	27.156	38,166	24,952	42,390
Actually evaporated, corrected for quality of steam.....do..	26,661	27,129	38,128	24,902	42,093
Factor of evaporation.....	1.197	1.198	1.197	1.197	1.198
Equivalent water evaporated into dry steam from and at 212 degrees....lbs..	31,913	32,500	45,639	29,808	50,427
WATER PER HOUR.					
Evaporated, corrected for quality of steam .....pounds..	4,443.6	4,521.5	3,812.8	2,490.2	7,015.5
Equivalent evaporation from and at 212 degrees.....do..	5,318.8	5,416.5	4,563.9	2,980.8	8,404.5
Equivalent evaporation from and at 212 degrees, per square foot of grate surface.....do..	253.3	257.9	217.3	141.9	400.2
Equivalent evaporation from and at 212 degrees per square foot of water-heating surface.....do..	4.87	4.96	4.18	2.73	7.70
ECONOMIC RESULTS.					
Water apparently evaporated per pound of coal (including moisture) under actual conditions.....pounds..	7.72	7.84	7.38	8.06	7.20
Apparent equivalent evaporation from and at 212 degrees per pound of coal (including moisture).....do..	9.24	9.38	8.84	9.65	8.62
Equivalent evaporation (dry steam) from and at 212 degrees per pound of dry coal.....do..	9.51	9.63	9.10	9.97	8.67
Equivalent evaporation (dry steam) from and at 212 degrees per pound of combustible.....do..	10.23	10.38	9.76	10.77	9.21
Potential evaporation, or evaporation had all the heat obtained from fuel been utilized in converting the water in boiler into dry saturated steam from average temperature of feed water and under average boiler pressure per pound of dry coal.....do..	7.95	8.04	7.61	8.33	7.25
Same, per pound of combustible.....do..	8.55	8.67	8.15	9	7.70
Equivalent potential evaporation from and at 212 degrees per pound of dry coal.....do..	9.52	9.63	9.11	9.97	8.68
Same, per pound of combustible.....do..	10.24	10.38	9.76	10.78	9.22

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CONCLUSIONS.

Of the mechanical details of the boiler little need be said, as they are sufficiently well known. The construction is such that tubes can be withdrawn and replaced with ease and rapidity, and the board witnessed this operation. It is of interest to record that for the purpose of cleaning the tubes of soot all were withdrawn and replaced during the nights following tests Nos. 1 and 2.

The boiler experimented on was designed for the moderate firing common in stationary practice, and while not differing in principles of construction and design of mechanical details from the marine type the evaporating tubes were $3\frac{15}{16}$ inches in diameter; so that while the ratio of H.S. to G.S. was high, 52:1, the gases were not as completely broken up as is the case with Niclausse boilers designed for marine use. In the marine type of boilers designed for battleships and cruisers the evaporating tubes are either all of $3\frac{1}{4}$ inches diameter or consist of a combination of $3\frac{1}{4}$ and $1\frac{9}{16}$-inch evaporating tubes, the lower rows being of the larger diameter. In the Niclausse torpedo-boat type of boiler all evaporating tubes are of the smaller diameter, $1\frac{9}{16}$ inches.

With the above in mind the performance of the boiler must be regarded as only fair for lower rates of combustion (tests 1, 2, 3 and 4) and as good for the higher rate, test 5.

At the conclusion of the tests the boiler was carefully examined, inside and out, being still hot and under about 40 pounds pressure, and no defects, injuries or leaks were discoverable beyond the warped furnace door above referred to.

On May 1, 1899, an experiment was made to determine the time required for getting up steam, of which the following is a record:

Started fires at 12.40 P. M. with wood and some oily waste. Used a few shovelfuls of fire from another boiler. Height of water in gage glass, $2\frac{5}{8}$ inches.

Steam formed at 1.01; height of water in gage glass, $9\frac{5}{8}$ inches.

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Time.	Pressure.	Time.	Pressure.
1·04½	10	1·17½	60
1·08	15	1·18	70
1·14	20 *	1·19	80
1·14½	25	1·19½	90
1·15	30	1·20	100
1·16	40	1·20⅔	110
1·17	50	1·21	121 †

* Started blower. † Safety valve blows.

The time, while good, was not the best possible, as too much water had been pumped into the boiler at the start.

TEST OF THE EVAPORATING PLANT OF THE *IRIS*.

The Bureau is well pleased with the efficiency of this distilling ship, and believes such a type of vessel to be a most essential addition to any squadron. Large tank vessels, while able to carry a large quantity of fresh water, must for the replenishment of their stock rely upon shore streams, which may not be readily available. On the contrary, a distilling-ship supply is the ocean itself, and the water distilled therefrom free from the impurities, which in even the best of natural waters have scale-forming properties.

Several tests of the plant of the *Iris* were made before the vessel left the United States, but a better idea of the average output is obtained from the observations made and recorded during the voyage to Manila, when a continuous demand was made for fresh water by the accompanying ships.

The *Iris* left New York on the 14th of October, 1898, bound for Manila. The first stop was made at Bahia, Brazil, and there the ship delivered approximately 1,320 tons of fresh water to the other ships. Some of this water (about 400 tons) had been brought from New York. The remainder was distilled on board. On the trip from Bahia to Sandy Point, Chile, the evaporating plant was in operation only long enough to supply the drinking tanks and make about 20 tons of fresh water for make-up feed for the ship itself. On November 27, on arrival at Sandy Point, the plant was put in full operation and all tanks and double bot-

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toms were filled. At Sandy Point the ship delivered 1,090 tons of fresh water to other ships. At Callao, Peru, after slight repairs to boilers had been made, the plant was again put in operation, and before leaving Callao the ship delivered 290 tons of fresh water to other ships, making in all 2,680 tons since leaving the United States, of which 2,280 tons had been made on board.

While at Sandy Point the plant was in operation for ten consecutive days and the actual quantity of water known. This, then, may be taken as a fair trial of performance. It was known that the output was approximately 1,100 tons, which gives a daily rate of 110 tons. This amount is just about half the rated capacity operating under the best conditions. A higher rate of economy, however, in coal cost of output was obtained by this moderate rate of distillation, and the data is of interest as being what may be considered a normal practical output when there is no desire to rush the plant at the expense of coal economy.

After the arrival of the *Iris* at Manila in the early part of May, 1899, a twenty-four-hour trial performance of the plant was held with the following results, which indicate the ability of the plant to produce readily about 200 tons of water per day.

Owing to insufficient steam supply from the main boiler in use at the time the maximum performance was not attained. One of the regular evaporator machinists being ill at the time, his place had to be taken by one comparatively inexperienced in taking care of the plant with all sets in operation. The weather was very warm, which naturally interfered with getting the best attendance from the men stationed on the evaporators.

RESULTS.

Duration of trial, hours	24
Grate area in use, square feet	70
Number of sets of evaporators in use (all)	4
Total quantity of water distilled, gallons	58,897
Total quantity of coal consumed, pounds	40,314
Unnecessary machinery in operation	Flushing pump.
Water distilled per pound of coal consumed, pounds	12.14
Water distilled per pound of coal consumed for distilling, pounds	12.88

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Excepting two condensers, which gave signs of leaking, all the machinery of the distilling plant operated satisfactorily. The affected condensers were cut out, and the distillation continued without total stoppage of the plant, two condensers doing the duty of four.

DATA TAKEN DURING THE TRIAL.

Steam pressures.	Pounds by gage.	Steam pressures.	Pounds by gage.
Tubes of first effect	64.3	Tubes of first effect	58
Shell of first effect	39	Shell of first effect	40
Tubes of second effect	38	Tubes of second effect	38
Shell of second effect	16	Shell of second effect	22
Tubes of third effect	14.7	Tubes of third effect	20
Shell of third effect	1	Shell of third effect	1.5
Tubes of first effect	62.5	Tubes of first effect	63
Shell of first effect	41.5	Shell of first effect	40
Tubes of second effect	39.7	Tubes of second effect	37.5
Shell of second effect	19	Shell of second effect	17
Tubes of third effect	19	Tubes of third effect	17
Shell of third effect	1	Shell of third effect	1.3

CONCENTRATION OF WATER IN SHELLS.

.....	Set A.	Set B.	Set C.	Set D.
First effect	3½	3½	3⅛	3
Second effect	2⅝	3⅛	3	3¼
Third effect	2¾	2⅞	3½	3¼

TEMPERATURES.

	Degrees.
Sea water	85
Feed water	184
Discharge water	115
Distilled water	125
Evaporator room	121.8
Evaporator room, highest	125
Evaporator room, lowest	100

NOTE.—With the initial pressure of steam and object in view, it was found to be impracticable to carry lower pressures in the shells of the third effects on account of priming.

* * *

The remaining portion of the report contains details of expenditures at each navy yard and station, enumerating all the

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PRINCIPAL DATA OF THE TRIAL TRIPS OF TORPEDO BOATS.

Name of vessel.	Type of vessel.	Displacement.	Type of engines. Vertical triple-expansion.	Cylinder diameters, in inches. First H.P.	First I.P.	Second L.P.	Stroke.	Number and type of boilers.	Total grate surface.	Total heating surface.	Trial speed.	Total, maximum I.H.P.	Total bunker capacity.	Total weight of machinery.	Present service.
		tons.	*screws.*				*ins.*		*sq. ft.*	*sq. ft.*	*knots.*		*tons.*	*tons.*	
Davis.....	Torpedo boat No. 12.	132	2	$11\frac{7}{8}$	19	$d\left\{\begin{matrix}22\frac{7}{8}\\22\frac{7}{8}\end{matrix}\right.$	15	2 Thornycroft.	88	4,763	23.41 May 23, '99.	*f* 1,750	40	52.04	At navy yard, Mare Island, Cal.
Farragut..	Torpedo boat No. 11.	273	2	20	29	$d\left\{\begin{matrix}30\\30\end{matrix}\right.$	18	3 Thornycroft.	196	9,912	30.13 Dec. 2, '98.	*f* 5,600	76	108.31	Do.
Fox.....	Torpedo boat No. 13.	132	2	$11\frac{7}{8}$	19	$d\left\{\begin{matrix}22\frac{7}{8}\\22\frac{7}{8}\end{matrix}\right.$	15	2 Thornycroft.	88	4,763	22.05 Aug. 1, '99.	*f* 1,750	40	51.92	Do.
Mackenzie..	Torpedo boat No. 17.	65	1	12	$19\frac{1}{2}$	$d\left\{\begin{matrix}22\\22\end{matrix}\right.$	16	2 Thornycroft.	40	2,168	20.11 May 25, '99.	*f* 850	15.3	26.13	At Newport, R. I.
Rodgers....	Torpedo boat No. 4.	142	2	12	$19\frac{1}{2}$	$d\left\{\begin{matrix}22\\22\end{matrix}\right.$	16	2 Mosher.	95	5,260	24.49 Mar. 19, '99.	2,295	44	50.82	At navy yard, New York.
Rowan.....	Torpedo boat No. 8.	182	2	$14\frac{1}{2}$	23	$d\left\{\begin{matrix}25\frac{3}{4}\\25\frac{3}{4}\end{matrix}\right.$	18	3 Mosher.	142.5	7,890	27.07 Apr. 22, '99.	*f* 3,200	60	82 71	At naval station, Puget Sound, Wash.

d = 2 L.P. cylinders. *f* = designed.

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vessels repaired at these places, and concluding with a most complete table of machinery data of all the vessels of the Navy, including details regarding vessels under construction.

While not reprinting all these details the table of principal trial data of torpedo boats and the remarks regarding the Cavite station are given in ending these extracts.

* * *

ENGINEERING PLANTS AT OUTLYING STATIONS.

While the Bureau is unable to foresee the governing policy most desirable in the future at these several newly-acquired stations, it can not but recommend that immediate steps be taken for establishing moderately large repair plants at each of these under this Bureau. I have included in my estimates a request for an appropriation of $25,000 each for the naval stations at Porto Rico and Honolulu, and have already taken steps to supply the naval station at Cavite with additional tools to those found there. The matter of further fitting up the station at Havana is under advisement, but no immediate steps are considered urgent owing to the proximity of that station to Key West. The present buildings at the Porto Rico station are substantial, and I consider it especially important that proper tools should be installed there.

In connection with the island of Guam, this Bureau has taken up the matter of supplying a distilling and refrigerating plant, but does not at present recommend any further installation of engineering material, owing to the uncertainties of the future.

A good general idea of the condition of the naval station at Cavite, and especially regarding the machine shops there, is obtained from the following extracts taken from the journal of Naval Cadet Daniel S. Mahony, written while on duty at that station.

The station is situated on a peninsula between Bakor Bay and Canacao Bay, the town of Cavite and Port San Felipe being also on the peninsula.

The buildings are old and in no way suited to a modern engineering establishment. The first one contains the machine shop and blacksmith shop, with boilers and engines to run the

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same. Three heavy stone walls divide it into four parts, and used for different classes of work.

The boilers are old-fashioned affairs on the Lancashire plan, furnaces running their whole length. The furnaces have Galloway tubes. Steam pressure is around 20 pounds, and much more would be hard to get with such a leaky combination of pipes and valves as is on these boilers.

The machine-shop engine is a vertical, direct-acting, single, inverted affair, feed pump attached, worked by an eccentric and slide valve worked by a second crank. It is of interest solely as a relic.

The machinery in the shops, as shown in the sketch, is poorly placed. All of it is of the old heavy type and none of it much good. The centers of most of the lathes wobble. The shapers are very old-fashioned. There is only one gap lathe in the shop. There is no floor; the earth is rough and uneven and the roof leaks. On one side the roof is of tin, with large skylights; the other half of the shop has a solid roof and no windows on one side; so much of the work is done by candle light.

The blacksmith shop has modern forges, none of them very large. It has a blower run by belting from the machine-shop shafting. There is a large steam hammer, valuable as a curiosity, and a small one, somewhat better. There are no facilities for heavy forging. The shop has the usual tools and French anvils.

The boiler shop is merely a big shed. It has five forges, two shearing and punching machines. There is also an immense old punching machine, long past use. Power is furnished by a small horizontal engine, taking its steam from Cornish boilers, of which there are two.

The foundry contains three brass furnaces and three cupolas (all of which need rebuilding), a small engine, and a blower. There is no elevator behind the cupolas; all metal has to be carried up on the platform behind them. Their capacity is one and one-half tons. A fairly heavy casting can be made directly in front of the cupolas, where is a track on which a truss is mounted on wheels. Heavy ladles can be swung from this truss. It is hard to say whether the natives do green-sand molding or dry-sand molding, as they use green sand and build fires under the molds. Cutting a pattern in two they never heard of, but with trowels and slickers they make very intricate molds.

The pattern shop is primitive. It contains a bench with one vise, a few chisels, planes, hand saws, bow saws, and a lathe. The last consists of two parts—a table on which are two centers, one adjustable, and a wheel some six feet in diameter, much like

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a cart wheel. A piece of wood to be turned is placed on the centers, and a rope belt put around it and around the big wheel, and while two men turn the latter a third holds the tool against the revolving wood. The natives much prefer, however, to sit upon a table, holding the piece of wood with their bare toes, and rounding it with a jack plane.

The marine ways are ordinary wooden affairs, a wooden bed sliding on rollers between wooden guides. The ways are moved by a large winch. The large ones are about 175 feet long and some 15 feet beam. The small ones are not over 100 feet long. The ways in the boat shed are an ordinary car track with a flat car on them. There is on the sea wall a large shears, good for about twenty-five tons, and a small crane for perhaps three or four tons. These are the only lifting facilities in the yard. Both are worked by hand.

An old-fashioned car track runs around the yard, and there are a few flat cars, but no locomotives.

The shipbuilding shop is the most modern thing in the yard. It has two Cornish boilers, and two large horizontal engines, modern. They have good governors and an expansion valve. A third eccentric on the shaft works a feed pump, which takes a brine mixture from a well. The machines in the shop are all rather old-fashioned, like everything else in the yard; still, if one can do with old-fashioned things, there should not be much trouble in getting along in a modern shop.

A large amount of work for the fleet has been done in the yard. In the foundry castings have been made for furnace fronts, bridge walls, pistons, pump chambers, etc., to say nothing of smaller articles. The blacksmiths have made heavy davits. In the boiler shop a boiler has had a new furnace fitted, been retubed, new stays put in—in fact, over half rebuilt. This work is worth bragging of, considering the means at hand.

Mr. Mahony followed the above description with a detailed account of the particular work he had had in charge connected with the repairs to tugs and refitting the machinery in the shops. In regard to the tugs he says:

Most of these boats have compound engines; four of French make, and one of English make, have the tandem type; the others have cross compound engines. There are only two arrangements of pumps and condensers. In one the condenser is athwartships; the engine columns serve for exhaust pipe, etc., and the

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air, circulation, feed and bilge pumps are worked direct from the crossheads, on the cross compound type. The tandem engines so rigged have only circulation and air pumps worked this way. Their feed pump is worked by a wrist pin on their slide valve eccentrics, and they have an independent bilge pump. All these engines, though heavy, are very compact, and while saving room and cheap in first cost, are admirably planned for beheading the people working around them.

In the second type the condenser forms the back engine column; pumps for air, circulation, feed and bilge behind the condenser, worked by a rocking lever from a crosshead. These engines are good working, easy to handle, and not hard to repair. Some of them have the low-pressure crank leading the high—not a good plan.

In addition to what he had written in his notes, Mr. Mahony said, while at the Bureau, that it was necessary to spread canvas under the leaking roof whenever a casting was to be poured. He said that the old boiler and engine of the shop had been removed and replaced by a boiler from one of the sunken ships of May 1, and that one of the twin-screw engines of a Spanish torpedo boat had been used for the shop engine. He said the Filipino workmen did very good work, but that they had no ingenuity. After the Filipinos left, Chinese were used in their place with some advantage, the Chinese being slightly better workmen than the Filipinos. The American workmen had not arrived when he left, nor had any of the American tools sent out from this country. He said that one of the *Olympia's* boilers had been retubed, and that it was necessary to draw down the ends of the tubes, which were slightly too large. He said that considerable work had been done on each of the ships.

The Bureau purchased and forwarded to the Cavite station the following tools for immediate use, pending a fuller expansion of the shops at the station:

One 20-inch by 12-foot lathe.	One 2-inch bolt threader.
One 16-inch by 10-foot lathe.	One pressure blower.
One 14-inch by 5-foot lathe.	One 8-inch pipe-threading and cutting machine.
One 2 by 24-inch flat turret lathe.	One set of assorted taps, stocks and dies.
One 42-inch vertical boring mill.	One 16 by 10-inch double traveling head shaper.
One universal grinding machine.	One universal milling machine.

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OBJECT LESSONS.

By A. B. Willits, U. S. Navy.

Marine engineers and modern shipbuilders will unquestionably concede that the most difficult feature to satisfactorily arrange in the machinery plant of a steamship is that of the piping, and particularly the portion of it which undergoes considerable change in length due to the temperature of the steam or hot water which it is required to convey.

With steam plants on shore ample space is primarily allotted in which to install piping of ideal simplicity and efficiency, and only culpable ignorance can occasion serious mistakes in the installation; but in the case of a steamship, and notably of a warship, the conditions are so entirely opposed to an easy solution of the problem as to make it necessary to give the closest study to the plans in order to avoid defective and even dangerous arrangements. Simple and direct leads are here seldom possible, as where the limit of machinery space is confined to the least number of cubic feet in which the apparatus can be effectively operated, and where overhead room is most meagre and rigidly blocked by a protective deck at about the water line, it is obvious that pipes connecting distant terminals must frequently be tortuous and the systems involved and complex.

The importance of properly providing for the expansion of the steam pipes in particular is the one detail in the piping problem which we wish to utilize in connection with our first object lesson in this paper. It would seem that the study of all the conditions bearing upon such an evidently essential attribute to an efficient plan would take precedence of many other engineering problems about which we read much; yet, strangely enough, this is not the case, and while the science of steam engineering is rapidly advancing on all other lines the disposition of the

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the steam pipes in marine work appears to improve but slowly, and we hear continual complaints of really avoidable defects in both the lead and accessibility of these conductors, as well as in the actual manner of construction.

True it is that few real casualties force immediate remedial attention to the matter, but all seagoing engineers know that frequently more mental distress and manual toil are involved in the care and keeping of the pipe joints than in all the other work connected with the operation of the engines and dependencies. Also it is true that enormously greater stresses are constantly being put upon castings and joints by lack of provision to properly accommodate the expansion of these pipes than was ever calculated for in the design. This, up to the point of rupture, is seldom evidenced, save in leaky joints which *will* not keep tight despite the most skillful attention and frequent remaking. How many of us there are who have met with these troublesome joints! Sometimes it is a three-branch casting, fitting all three flanges of connecting pipes, when *cold*, perfectly, but when all the pipes are hot their expansion would make it absolutely impossible to remake the three joints were the casting then disconnected. Hence, under steam, great and abnormal expansive strains are brought on the connections, producing weeping and leaking until, perhaps, a crack in a nozzle points to the true cause of the trouble.

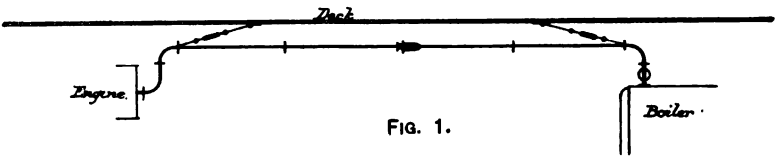

FIG. 1.

Of course the ideal steam lead is short and direct and has the two extremities anchored towards each other, while between the anchors are placed proper slip-joints which can accommodate all increase in lineal dimensions. (See Fig. 1.) But where this system cannot be followed we must not trust to bends and crooks to take up the expansion satisfactorily. Long loops provide, of course, a flexibility not found in short bends, but

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even at the best this method brings side strains on the flanges and castings at elbows and bends which are forever tending to cockbill flanges and make joints difficult to keep tight, if they do not do more than that, by overstraining these parts. A good slip-joint in line of greatest expansion used in connection with "anchors" at such points as will compel accommodation by these slip-joints, are a necessary part of efficient piping, except where a trunnion joint, (such as adopted by Yarrow and described in object lessons in the August JOURNAL) can be adopted. Where to place the slip-joints, however, is as important as to have them, and an actual case in modern work is illustrated here (Fig. 2), which can well be studied as a bad example indeed.

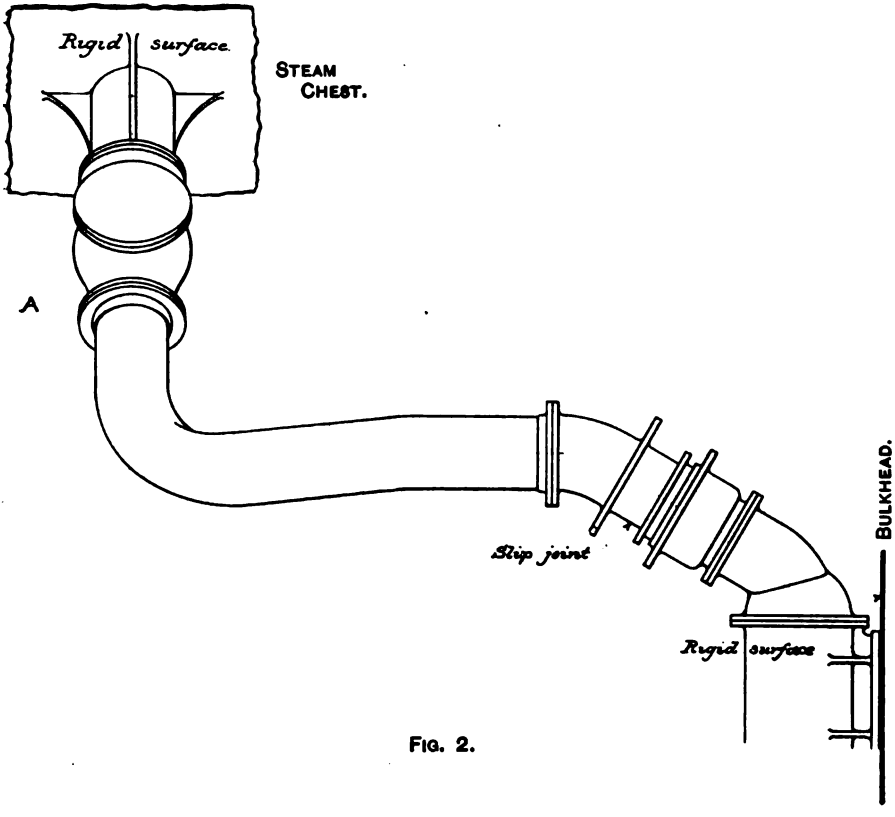

FIG. 2.

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The figure is drawn in partial perspective, scarcely usual, yet most easily "read." Conceive a pressure of 160 pounds per square inch in this 15-inch pipe. Imagine then the elongation due to expansion by the heat, and observe the difficulty in compelling the slip-joint to take this up. Every tendency is for the pipe to spring that much *away* from the slip-joint, the steam pressure on the elbow (projected area of the pipe) assisting it. This pressure acting at the leverage it there has from elbow to the steam chest (about three feet) brings an enormous strain on the casting at the steam chest; a strain never intended or calculated for, so that as a result, a crack at the casting might well be expected, and that result was secured strictly according to Hoyle. To make matters worse, the slip-joint bolts had no shoulders to prevent *extraction* movement of the joint, being instead, provided with stiff springs to resist such action, but these springs failed to meet the expectation of the designer. This slip-joint is faulty in other ways, not being in the proper part of the pipe. This will be evident to anyone who will sketch in an imaginary outline of the pipe increased in all lineal directions by the approximate expansion.

Leaving the matter of piping to the thoughtful, we would like to illustrate a peculiar condition of the propeller shaft of the *Helena*, which was ruptured last August while the engines were running at 165 turns per minute. Examination by the Board of Survey showed the shaft to have broken in a helical form on one side and straight on the other as shown in the sketch (Fig. 3), and at about two feet six inches forward of the after strut.

The break is an object lesson to inspectors of hollow shafting, as the "axial hole" was found to be $\frac{17}{32}$ of an inch out of central, making the thickness of metal on one side $1\frac{28}{32}$ inches, while on the opposite side it was only $\frac{27}{32}$ inch. This great difference in the walls of the shaft taken in connection with the fact that the after strut bearing was considerably worn down, bringing a sort of eccentric motion on the shaft, caused a crack to start in the weak part and a speedy rupture to follow.

In noting the above one is reminded of the frequent reports of shaft failures, and attributing much of the trouble to corrosion at

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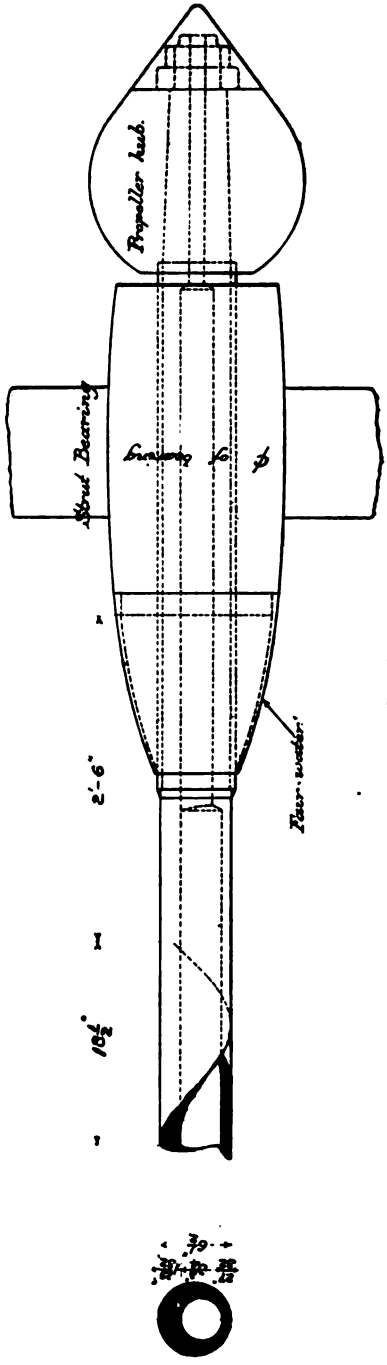

FIG. 3.

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covered points. This experience, as far as weakening shafts by corrosion, has been a recent experience in the Navy, the shafts of the *Marietta* and *Wheeling* both having seriously corroded under the brass casing. Faulty fitting of casing was the primary cause, and it is important to further guard against such invisible deterioration by grooving the inner surface of casing and propeller hub also at the ends where the joints are to be made, and, after fitting, pump into the grooves some plastic waterproof material, having first drilled inlet and vent holes, and then plug up the holes. If it is thus made impossible for water to enter at the joints, it is not material if the casing does not absolutely hug the shaft "watertight" throughout. At the propeller end this is most important also, as here corrosion would more quickly reduce the shaft to point of rupture.

The "old, old story is told again" in the recent accident to the *Stringham*. It is only a revival of another object lesson, yet no number of warnings will securely guard the future from repetition of the carelessness. The following is from a report on the occurrence:

"The torpedo boat *Stringham* was taken out on the Delaware River for engine trials with fire under the two forward boilers only, having had a similar trial with the two after boilers on a previous date. After letting go of the tug at the mouth of the Christiana River we steamed down the Delaware River with steam varying from 100 to 200 pounds pressure per square inch, engines, pumps, blowers, etc., all running well, speed of main engines averaging from 100 to 300 per minute. Just before reaching Reedy Island we had the steam at 200 pounds for a second spurt at this pressure. We had just opened the throttle valve when a sharp jar and report was given out by the port engine, followed by a grinding noise. The engine was stopped at once. After careful external examination nothing could be discovered that would have caused the trouble, and we continued on with the starboard engine running and in a short time started up again with the port engine, which then seemed to run quietly. On arriving at our dock we at once opened up the steam chest common to the high-pressure and intermediate-pressure cylinders and found that a

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small, solid wrench had been, through some one's carelessness, left in the valve chamber, and had worked into the port chamber and been caught by the valve. The result was a breaking out of the bridge between the ports and also breaking the valve. No examination has as yet been made of the valve-gear links, piston and connecting rods, but same will be done at once. The accident necessitated the making of a complete new pair of cylinders."

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THE PROGRESS IN STEAM NAVIGATION.

By Sir William H. White.*

Steamship design, to be successful, must always be based on experiment and experience as well as on scientific principles and processes. It involves problems of endless variety and great complexity. The services to be performed by steamships differ in character, and demand the production of many distinct types of ships and propelling apparatus. In all these types, however, there is one common requirement—the attainment of a specified speed. And in all types there has been a continuous demand for higher speed.

Stated broadly, the task set before the naval architect in the design of any steamship is to fulfill certain conditions of speed in a ship which shall not merely carry fuel sufficient to traverse a specified distance at that speed, but which shall carry a specified load on a limited draught of water. Speed, load, power and fuel supply are all related, and the two last have to be determined in each case. In some instances, other limiting conditions are imposed affecting length, breadth, or depth. In all cases there are three separate efficiencies to be considered—those of the ship, as influenced by her form; of the propelling apparatus, including the generation of steam in the boilers and its utilization in the engines; and of the propellers. Besides these considerations the designer has to take account of the materials and structural arrangements which will best secure the association of lightness with strength in the hull of the vessel. He must select those types of engines and boilers best adapted for the service proposed. Here the choice must be influenced by the length of the voyage, as well as the exposure it may involve to storm and stress.

* Extracts from address before the Mechanical Science Section of the British Association.

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Obviously the condition to be fulfilled in an oceangoing passenger steamer of the highest speed, and in a cross-channel steamer designed to make short runs at high speed in comparatively sheltered waters, must be radically different. And so must be the conditions in a swift seagoing cruiser of large size and great coal endurance, from those best adapted for a torpedo boat or destroyer. There is, in fact, no general rule applicable to all classes of steamships; each must be considered and dealt with independently, in the light of the latest experience and improvements. For merchant ships there is always the commercial consideration, Will it pay? For warships there is the corresponding inquiry, Will the cost be justified by the power and efficiency of the proposed ship?

CHARACTERISTICS OF PROGRESS IN STEAM NAVIGATION.

Looking at the results so far attained, it may be said that progress in steam navigation has been marked by the following characteristics: (1) Growth in dimensions and weights of ships, and large increase in engine power as speeds have been raised. (2) Improvements in marine engineering, accompanying increase of steam pressure. Economy of fuel and reduction in the weight of propelling apparatus in proportion to the power developed. (3) Improvements in the materials used in shipbuilding; better structural arrangements; relatively lighter hulls and larger carrying power. (4) Improvements in form, leading to diminished resistance and economy of power expended in propulsion. These general statements represent well-known facts, so familiar indeed that their full significance is often overlooked. It would be easy to multiply illustrations, but only a few representative cases will be taken.

TRANSATLANTIC PASSENGER STEAMERS.

Transatlantic service naturally comes first. It is a simple case, in that the distance to be covered has remained practically the same, and that for most of the swift passenger steamers cargo-carrying capacity is not a very important factor in the design. In 1840 the Cunard steamer *Britannia*, built of wood, propelled by paddle wheels, maintained a sea speed of about 8½ knots. Her

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steam pressure was 12 pounds per square inch. She was 207 feet long, about 2,000 tons in displacement, her engines developed about 750 horsepower, and her coal consumption was about 40 tons per day, nearly 5 pounds of coal per indicated horsepower per hour. She had a full spread of sail. In 1871 the White Star steamship *Oceanic*—first of that name—occupied a leading position. She was iron built, propelled by a screw, and maintained a sea speed of about 14½ knots. The steam pressure was 65 pounds per square inch, and the engines were on the compound principle. She was 420 feet long, about 7,200 tons in displacement, her engines developed 3,000 horsepower, and she burnt 65 tons of coal per day, or about two pounds per indicated horsepower per hour. She carried a considerable spread of sail. In 1889 the White Star steamer *Teutonic* appeared, propelled by twin screws, and practically with no sail power. She is steel built, and maintains a sea speed of about 20 knots. The steam pressure is 180 pounds per square inch, and the engines are on the triple-expansion principle. She is about 565 feet long, 16,000 tons in displacement, 17,000 horsepower indicated, with a coal consumption of about 300 tons a day, or from 1.6 to 1.7 pounds per indicated horsepower per hour. In 1894 the Cunard steamship *Campania* began her service, with triple-expansion engines, twin screws and no sail power. She is about 600 feet long, 20,000 tons displacement, develops about 28,000 horsepower at full speed of 22 knots, and burns about 500 tons of coal per day. The new *Oceanic*, of the White Star Line, is just beginning her work. She is of still larger dimensions, being 704 feet in length, and over 25,000 tons displacement. From the authoritative statements made, it appears that she is not intended to exceed 22 knots in speed, and that the increase in size is to be largely utilized in additional carrying power. The latest German steamers for the transatlantic service are also notable. A speed of 22½ knots has been maintained by the *Kaiser Wilhelm der Grosse*, which is 25 feet longer than the *Campania*. Two still larger steamers are now building, The *Deutschland* is 660 feet long, and 23,000 tons displacement; her engines are to be of 33,000 horsepower, and it is estimated that she will average 23 knots. The other ves-

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sel is said to be 700 feet long, and her engines are to develop 36,000 horsepower, giving an estimated speed of 23½ knots. All these vessels have steel hulls and twin screws. It will be noted that to gain about three knots an hour nearly 50 per cent. will have been added to the displacement of the *Teutonic*, the engine power and coal consumption will be doubled, and the cost increased proportionally.

Sixty years of continuous effort and strenuous competition on this great "ocean ferry" may be summarized in the following statement: Speed has been increased from 8½ to 22½ knots; the time on the voyage has been reduced to about 38 per cent. of what it was in 1840. Ships have been more than trebled in length, about doubled in breadth, and increased tenfold in displacement. The engine power has been made forty times as great. The ratio of horsepower to the weight driven has been increased fourfold. The rate of coal consumption—measured per horsepower per hour—is now only about one-third what it was in 1840. To drive 2,000 tons weight across the Atlantic at a speed of 8½ knots per hour about 550 tons of coal were then burnt; now, to drive 20,000 tons across at 22 knots, about 3,000 tons of coal are burnt.

With the low pressure of steam and heavy, slow-moving paddle engines of 1840, each ton weight of machinery, boilers, etc., produced only about two horsepower. With modern twin-screw engines and high steam pressure, each ton weight of propelling apparatus produces from six horsepower to seven horsepower. Had the old rate of coal consumption continued, instead of 3,000 tons of coal, 9,000 tons would have been required for a voyage at 22 knots. Had the engines been proportionately as heavy as those in use sixty years ago they would have weighed about 14,000 tons. In other words, machinery, boilers and coals would have exceeded in weight the total weight of the *Campania* as she floats to-day. There could not be a more striking illustration than this of the close relation between improvements in marine engineering and the development of steam navigation at high speeds.

Equally true is it that this development could not have been accomplished but for the use of improved materials and structural

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arrangements. Wood, as the principal material for the hulls of high-powered swift steamers, imposed limits upon dimensions, proportions and powers which would have been a bar to progress. The use of iron first, and since of steel, removed those limits. The percentage of the total displacement devoted to hull in a modern Atlantic liner of the largest size is not much, if at all, greater than was the corresponding percentage in the wood-built *Britannia* of 1840, of one-third the length and one-tenth the total weight. Nor must it be overlooked that with increase in dimensions have come considerable improvements in form favoring economy in propulsion. This is distinct from the economy resulting from increase in size, which Brunel appreciated thoroughly half a century ago when he designed the *Great Britain* and the *Great Eastern.*

The importance of a due relation between the lengths of the "entrance and run" of steamships and their intended maximum speeds, and the advantages of greater length and fineness of form as speeds are increased, were strongly insisted upon by Scott Russell and Froude. Naval architects, as a matter of course, now act upon the principle, so far as other conditions permit. For it must never be forgotten that economy of propulsion is only one of many desiderata which must be kept in view in steamship design. Structural weight and strength, seaworthiness and stability all claim attention, and may necessitate modifications in dimensions and form which do not favor the maximum economy of propulsion. Increase in length and weight have largely assisted the marvellous regularity of service now attained on the longest passages by swift steamships. Even the largest vessels at times have to yield to the forces of nature displayed in wind and sea. But these conditions are more rarely reached in the longer and heavier ships.

SWIFT PASSENGER STEAMERS FOR LONG VOYAGES.

Changes similar to those described for the transatlantic service have been in progress on all the great lines of ocean traffic. In many instances increase in size has been due not only to increase in speed, but to enlarged carrying power, and the ex-

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tension of the lengths of voyages. No distance is now found too great for the successful working of steamships, and the sailing fleet is rapidly diminishing in importance. So far as long-distance steaming is concerned, the most potent factor has undoubtedly been the marvellous economy of fuel that has resulted from higher steam pressures and greater expansion. In all cases, however, advances have been made possible not merely by economy of fuel, but by improvements in form, structure and propelling apparatus, and by increased dimensions. This might be illustrated by many interesting facts drawn from the records of the great steamship companies which perform the services to the far East, Australia, South America, and the Pacific. I must be content, however, with the statement of a few facts regarding the development of the fleet of the Peninsular and Oriental Company. The paddle steamer *Willam Fawcett*, of 1829, was about 75 feet long, 200 tons displacement, of 60 nominal horsepower—probably about 120 indicated horsepower—and in favorable weather steamed at a speed of 8 knots. Her hull was of wood, and, like all the steamers of that date, she had considerable sail power.

In 1853 the *Himalaya*, iron-built screw steamer of this line, was described "of larger dimensions than any then afloat, and of extraordinary speed." She was about 340 feet long, over 4,000 tons load displacement, 2,000 indicated horsepower on trial, with an average sea speed of about 12 knots. The steam pressure was 14 pounds per square inch, and the daily coal consumption about 70 tons. This vessel was transferred to the Royal Navy, and did good service a troopship for forty years. In 1893 another *Himalaya* was added to the company's fleet. She was steel-built, nearly 470 feet long and 12,000 tons load displacement, with over 8,000 indicated horsepower and a capability to sustain 17 to 18 knots at sea on a daily consumption of about 140 tons of coal. The steam pressure is 160 pounds per square inch, and the engines are of the triple-expansion type. Comparing the two *Himalayas*, it will be seen that in forty years the length has been increased about 40 per cent., displacement trebled, horsepower quadrupled, and speed increased 50 per cent. The

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proportion of horsepower to displacement has only been increased as three to four, enlarged dimensions having secured relative economy in propulsion. The rate of coal consumption has been probably reduced to about one-third of that in the earlier ship.

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CARGO AND PASSENGER STEAMERS.

Cargo steamers, no less than passenger steamers, have been affected by the improvement mentioned. Remarkable developments have occurred recently, not merely in the purely cargo carrier, but in the construction of vessels of large size and good speed, carrying very great weights of cargo and considerable numbers of passengers. The much decried "ocean tramp" of the present day exceeds in speed the passenger and mail steamer of fifty years ago. Within ten years vessels in which cargo carrying is the chief element of commercial success have been increased in length from 300 feet or 400 feet to 500 feet or 600 feet; in gross register tonnage from 5,000 to over 13,000 tons, and in speed from 10 or 12 knots to 15 or 16 knots. Vessels are now building for the Atlantic service which can carry 12,000 to 13,000 tons deadweight, in addition to passengers, while possessing a sea speed as high as that of the swiftest mail steamers afloat in 1880. Other vessels of large carrying power and good speed are running on much longer voyages, such as to the Cape and Australia.

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INCREASE IN SIZE AND SPEED OF WARSHIPS.

Turning from seagoing ships of the mercantile marine to warships, one finds equally notable facts in regard to increase in speed, associated with enlargement in dimensions and advance in propelling apparatus, materials of construction, structural arrangements and form. Up to 1860 a measured-mile speed of 12 to 13 knots was considered sufficient for battleships and the largest classes of cruisers. All these vessels possessed good sail power, and used it freely as an auxiliary to steam or as an alternative when cruising or making passages. When armored battleships were built—1859—the speeds on measured-mile trials were raised to 14 or 14½ knots, and so remained for about twenty

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years. Since 1880 the speeds of battleships have been gradually increased, and in the latest types the measured-mile speed required is 19 knots. Up to 1870 the corresponding speeds in cruisers ranged from 15 to 16 knots. Ten years later the maximum speeds were 18 to 18½ knots in a few vessels. Since then trial speeds of 20 to 23 knots have been attained, or are contemplated. There is, of course, a radical distinction between these measured-mile performances of warships and the average sea speeds of merchant steamers above described. But for purposes of comparison between warships of different dates measured-mile trials may fairly be taken as the standard. For long-distance steaming the power developed would necessarily be much below that obtained for short periods, and with everything at its best. This is frankly recognized by all who are conversant with warship design, and fully allowed for in estimates of sea speeds.

On the other hand, it is possible to point to sea trials made with recent types where relatively high speeds have been maintained for long periods. For example, the battleship *Royal Sovereign* has maintained an average speed of 15 knots from Plymouth to Gibraltar, and the *Renown* has maintained an equal speed from Bermuda to Spithead. As instances of good steaming by cruisers, reference may be made to 60-hour trials with the *Terrible*, when she averaged over 20 knots, and to the run home from Gibraltar to the Nore by the *Diadem*, when she exceeded 19 knots. Vessels of the *Pelorus* class, of only 2,100 tons displacement, have made long runs at sea, averaging over 17 knots. Results such as these represent a substantial advance in speed of Her Majesty's ships in recent years.

Similar progress has been made in foreign warships built abroad as well as in this country. It is not proposed to give any facts for these vessels, or to compare them with results obtained by similar classes of ships in the Royal Navy. Apart from full knowledge of the conditions under which speed trials are made, a mere statement of speeds attained is of no service. One requires to be informed accurately respecting the duration of the trial, the manner in which engines and boilers are worked, the extent to which boilers are "forced," or the proportion of

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heating surface to power indicated, the care taken to eliminate the influence of tide or current, the mode in which the observations of speed are made, and other details, before any fair or exact comparison is possible between ships. For present purposes, therefore, it is preferable to confine the illustrations of increase in speed in warships to results obtained under Admiralty conditions, and which are fairly comparable.

A great increase in size has accompanied this increase in speed, but it has resulted from other changes in modern types, as well as from the rise in speed. Modern battleships are of 13,000 to 15,000 tons, and modern cruisers of 10,000 to 14,000 tons, not merely because they are faster than their predecessors, but because they have greater powers of offense and defense, and possess greater coal endurance. Only a detailed analysis, which cannot now be attempted, could show what is the actual influence of these several changes upon size and cost, and how greatly the improvements made in marine engineering and shipbuilding have tended to keep down the growth in dimensions consequent on increase in load carried, speed attained, and distance traversed. It will be noted also that large as are the dimensions of many classes of modern warships, they are all smaller in length and displacement than the largest mercantile steamers above described. There is, no doubt, a popular belief that the contrary is true, and that warships exceed merchant ships in tonnage. This arises from the fact that merchant ships are ordinarily described, not by their displacement tonnage, but by their registered tonnage, which is far less than their displacement.

As a matter of fact, the largest battleships are only of about two-thirds the displacement of the largest passenger steamers, and from 200 feet to 300 feet shorter. The largest cruisers are from 100 feet to 200 feet shorter than the largest passenger steamers, and about 60 per cent. of their displacement. In breadth the warships exceed the largest merchant steamers by from 5 feet to 10 feet. This difference in form and proportions is the result of radical differences in the vertical distribution of the weights carried, and is essential to the proper stability of the

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warships. Here we find an illustration of the general principle underlying all ship designing. In selecting the forms and proportions of a new ship considerations of economical propulsion can not stand alone. They must be associated with other considerations, such as stability, protection and maneuvering power, and in the final result economy of propulsion may have to be sacrificed to some extent in order to secure other essential qualities.

ADVANTAGES OF INCREASED DIMENSIONS.

Before passing on, it may be interesting to illustrate the gain in economy of propulsion resulting from increase in dimensions by means of the following table, which gives particulars of a number of typical cruisers, all of comparatively recent design:

.....	*No. 1.*	*No. 2.*	*No. 3.*	*No. 4.*	*No. 5.*
Length, feet	280	300	360	435	500
Breadth, feet	35	43	60	69	71
Mean draught, feet	13	16.50	23.75	24.50	26.25
Displacement, tons	1,800	3,400	7,400	11,000	14,200
I.H.P. for 20 knots	6,000	9,000	11,000	14,000	15,500
I.H.P. per ton of displacement	3.3	2.65	1.48	1.27	1.09

The figures given are the results of actual trials, and embody, therefore, the efficiencies of propelling machinery, propellers and forms of the individual ships. Even so, they are instructive. Comparing the first and last, for example, it will be seen that while the displacement is increased nearly eightfold, the power for 20 knots is only increased about 2.6 times. If the same types of engines and boilers had been adopted in these two vessels (which was not the case, of course), the weights of propelling apparatus and coal for a given distance would have been proportional to the respective powers; that is to say, the larger vessel would have been equipped with only 2.6 times the weight carried by the smaller. On the other hand, roughly speaking, the disposable weights, after providing for hulls and fittings in these two vessels, might be considered to be proportional to their displacements. As a matter of fact, this assumption is distinctly in favor of the smaller ship. Adopting it, the larger ves-

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sel would have about eight times the disposable weight of the smaller, while the demand for propelling apparatus and fuel would be only 2.6 times that of the smaller vessel. There would, therefore, be an enormous margin of carrying power in comparison with displacement in the larger vessel. This might be devoted, and, in fact, was devoted, partly to the attainment of a speed considerably exceeding 20 knots—which was a maximum for the smaller vessel—partly to increased coal endurance and partly to protection and armament.

Another interesting comparison may be made between vessels Nos. 4 and 5 in the preceding table, by tracing the growth in power necessary to drive the vessels at speeds ranging from 10 knots up to 22 knots.

It will be noted from the following table that up to the speed of 18 knots there is a fairly constant ratio between the powers required to drive the two ships. As the speeds are increased the larger ship gains, and at 22 knots the same power is required in both ships. The smaller vessel, as a matter of fact, was designed for a maximum speed of 20½ knots, and the larger for 22 knots. Unless other qualities had been sacrificed, neither space nor weight could have been found in the smaller vessel for machinery and coals corresponding to 22 knots. The figures are interesting, however, as illustrations of the principle that economy of propulsion is favored by increase in dimensions as speeds are raised.

.....	*No. 4.*	*No. 5.*
knots.	*horsepower.*	*horsepower.*
10	1,500	1,800
12	2,500	3,100
14	4,000	5,000
16	6,000	7,500
18	9,000	11,000
20	14,000	15,500
22	23,000	23,000

Going a step further, it may be assumed that in unsheathed cruisers of this class about 40 per cent. of the displacement will be required for the hull and fittings, so that the balance, or "dis-

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posable weight," would be about 60 per cent., say, 6,600 tons for the smaller vessel and 8,500 tons for the larger, a gain of nearly 2,000 tons for the latter. If the speed of 22 knots were secured in both ships, with machinery and boilers of the same type, the larger ship would, therefore, have about 2,000 tons greater weight available for coals, armament, armor and equipment. These illustrations of well-known principles have been given simply for the assistance of those not familiar with the subject, and they need not be carried further. More general treatment of the subject, based on experimental and theoretical investigation, will be found in text books of naval architecture.

SWIFT TORPEDO VESSELS.

Torpedo flotillas are comparatively recent additions to war fleets. The first torpedo boat was built by Mr. Thornycroft for the Norwegian Navy in 1873; and the same gentleman built the first torpedo boat for the Royal Navy in 1877. The construction of the larger class known as "torpedo-boat destroyers," dates from 1893. These various classes furnish some of the most notable examples extant of the attainment of extraordinarily high speeds for short periods, and in smooth water, by vessels of small dimensions. Their qualities and performances, therefore, merit examination. Mr. Thornycroft may justly be considered the pioneer in this class of work. Greatly impressed by the combination of lightness and power embodied in railway locomotives, Mr. Thornycroft applied similar principles to the propulsion of small boats, and obtained remarkably high speeds. His work became more widely known when the results were published of a series of trials, conducted in 1872 by Sir Frederick Bramwell, on a small vessel named the *Miranda*. She was only 45 feet long, and weighed four tons, yet she exceeded 16 knots on trial. The Norwegian torpedo boat, built in 1873, was 57 feet long, 7½ tons, and of 15 knots; the first English torpedo boat of 1877 was 81 feet long, 29 tons, and attained 18½ knots.

Mr. Yarrow also undertook the construction of small, swift vessels at a very early date, and has greatly distinguished himself throughout the development of the torpedo flotilla. Messrs.

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White, of Cowes, previously well known as builders of steamboats for use on board ships, extended their operations to the construction of torpedo boats. These three firms for a considerable time practically monopolized this special class of work in this country. Abroad they had able competitors in Normand in France, Schichau in Germany, and Herreshoff in the United States. Keen competition led to successive improvements, and rapid rise in speed.

During the last six years the demand for a fleet of about one hundred destroyers, to be built in the shortest possible time, involved the necessity for increasing the sources of supply. At the invitation of the Admiralty a considerable number of the leading shipbuilding and engineering firms have undertaken, and successfully carried through, the construction of destroyers varying from 26 to 33 knots in speed, although the work was necessarily of a novel character, involving many difficulties. As the speeds of torpedo vessels have risen, so have their dimensions increased. Within the class, the law shown to hold good in larger vessels applies equally. In 1877 a first-class torpedo boat was 81 feet long, under 30 tons weight, developed 400 horsepower, and steamed 18½ knots. Ten years later the corresponding class of boat was 135 feet long, 125 tons weight, developed 1,500 horsepower, and steamed 23 knots. In 1897 it had grown to 150 feet in length, 140 to 150 tons, 2,000 horsepower, and 26 knots. Destroyers are not yet of seven years' standing, but they come under the rule. The first examples—1893—were 180 feet long, 240 tons, 4,000 horsepower and 26 to 27 knots. They were followed by 30-knot vessels, 200 feet to 210 feet long, 280 to 300 tons, 5,500 to 6,000 horsepower. Vessels now in construction are to attain 32 to 33 knots, their lengths being about 230 feet, displacements 360 to 380 tons, and engine power 8,000 to 10,000 horsepower.

Cost has gone up with size and power, and the limit of progress in this direction will probably be fixed by financial considerations, rather than by constructive difficulties, great as these are as speeds rise. It may be interesting to summarize the distinctive features of torpedo vessel design.

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(1) The propelling apparatus is excessively light in proportion to the maximum power developed. Water-tube boilers are now universally adopted, and on speed trials they are "forced" to a considerable extent. High steam pressures are used. The engines are run at a high rate of revolution—often at 400 revolutions per minute. Great care is taken in every detail to economize weight. Speed trials at maximum power extend over only three hours. On such trials in a destroyer each ton weight of propelling apparatus produces about 45 indicated horsepower. Some idea of the relative lightness of the destroyer's machinery and boilers will be obtained when it is stated that in a large modern cruiser with water-tube boilers, high steam pressure and quick-running engines, the maximum power obtained on an eight hours' trial corresponds to about 12 indicated horsepower per ton of engines, boilers, etc. That is to say, the proportion of power to weight of propelling apparatus is from three and a half to four times as great in the destroyer as it is in the cruiser.

(2) A very large percentage of the total weight—or displacement—of a torpedo vessel is assigned to propelling apparatus. In a destroyer of 30 knots trial speed, nearly one-half the total weight is devoted to machinery, boilers, etc. In the swiftest cruisers of large size, the corresponding allocation of weight is less than 20 per cent. of the displacement, and in the largest and fastest mail steamers it is about 20 to 25 per cent.

(3) The torpedo vessel carries a relatively small load of fuel, equipment, etc. Taking a 30-knot destroyer, for example, the speed trials are made with a load not exceeding 12 to 14 per cent. of the displacement. In a swift cruiser the corresponding load would be from 40 to 45 per cent., or proportionately more than three times as great. What this difference means may be illustrated by two statements. If the load were trebled, and the vessel correspondingly increased in draught and weight, the speed attained with the same maximum power would be about three knots less. If, on the other hand, the vessel were designed to attain 30 knots on trial with the heavier load, her displacement would probably be increased about 70 to 80 per cent.

(4) The hull and fittings of the torpedo vessel are exceedingly

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light in relation to the dimensions and engine power. For many parts of the structure steel of high tensile strength is used. Throughout the utmost care is taken to economize weight. In small vessels, for special service, many conditions can be accepted which would be inadmissible in larger sea going vessels. The result of all this care is the production of hull structures having ample general strength, but very little local strength; but notwithstanding all the accidents of navigation and collisions that have occurred in this class of vessel—and they have not been few—not one has yet foundered at sea.

These conditions are essential to the attainment of very high speeds for short periods. They resemble the conditions ruling the design of cross-channel steamers, so far as relative lightness of propelling apparatus, small load and light scantlings are concerned. The essential differences lie in the requirements for passenger accommodation as compared with the requirements for armament of the torpedo vessel. No one has yet proposed to extend the torpedo-vessel system to seagoing ships of large dimensions. Very similar conditions for the propelling apparatus have been accepted in a few cruisers of considerable dimensions, wherein high speeds for short periods were required. It is, however, unquestionable that in many ways, and particularly in regard to machinery design, the construction of torpedo vessels has greatly influenced that of larger ships.

One important consideration must not be overlooked. For short-distance steaming at high speeds economy in coal consumption is of little practical importance, and it is all-important to secure lightness of propelling apparatus in relation to power. For long-distance steaming, on the contrary, economy in coal consumption is of primary importance; and savings in weight of propelling apparatus, even of considerable amount, may be undesirable if they involve increased coal consumption. Differences of opinion prevail as to the real economy of fuel obtainable with boilers and engines such as are fitted to torpedo vessels. Claims are made for some vessels which represent remarkable economy. Only enlarged experience can settle these questions. Endurance is also an important quality in seagoing ships of

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large size; not merely in structure, but in propelling apparatus. The extreme lightness essential in torpedo vessels obviously does not favor endurance, if high powers are frequently or continuously required. Still it cannot be denied that the results obtained in torpedo vessels show such a wide departure from those usual in seagoing ships as to suggest the possibility of some intermediate type of propelling apparatus applicable to large seagoing ships, and securing sufficient durability and economy of fuel in association with further savings of weight.

THE PARSONS TURBO-MOTOR.

The steam turbo-motor, introduced by Mr. Charles Parsons, with its very high rate of revolution, reduces the weights of machinery, shafting and propellers greatly below the weight required in the quickest-running engines of the reciprocating type. This reduction in the proportion of weight to power carries with it, of course, the possibility of higher speed in a vessel of given dimensions, and when large powers are employed the absolute gain is very great. An illustration of this has been given by Mr. Parsons in the *Turbinia*. That remarkable vessel is 100 feet long, and of 44½ tons displacement, but she has attained 33 to 34 knots in short runs. There are three shafts, each carrying three screw propellers, each shaft driven by a steam turbine making over 2,000 revolutions at full speed, when an aggregate of more than 2,000 horsepower is developed. A water-tube boiler of special design supplies steam of 175 pounds pressure, and is exceptionally light for the steam produced, being highly forced.

The whole weight of machinery and boilers is 22 tons; in other words, about 100 horsepower indicated is produced for each ton weight of propelling apparatus. This is rather more than twice the proportion of power to weight as compared with the lightest machinery and boilers fitted in torpedo boats and destroyers. It will be noted that in the *Turbinia*, as in the destroyers, about half the total weight is devoted to propelling apparatus, and in both instances the load carried is relatively small. The secret of the extraordinary speed is to be found in

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the extreme lightness of propelling apparatus and small load. No doubt in the *Turbinia* lightness has been pushed further than it would be in vessels of larger size and greater power. In such vessels a lower rate of revolution would probably be accepted, additional motors would be fitted for maneuvering and going astern, boilers of relatively greater weight would be adopted, and other changes made. But after making ample allowance for all such increases in weight, it is unquestionable that considerable economies must be possible with rotary engines. Two other vessels of the destroyer type with turbo-motors—one for the Royal Navy—are now approaching completion. Their trials will be of great interest, as they will furnish a direct comparison with vessels of similar size and form, fitted with similar boilers and driven by reciprocating engines.

On the side of coal consumption Mr. Parsons claims at least equality with the best triple-expansion engines. Into the other advantages attending the use of rotary engines it is not necessary now to enter. Reference must be made, however, to one matter in which Mr. Parsons has done valuable and original work. In torpedo vessels of high speed the choice of the most efficient propellers has always been a matter of difficulty, and the solution of the problem has, in many instances, involved extensive experimental trials. By means of alterations in propellers alone very large increases in speed have been effected; and, even now, there are difficulties to be faced. When Mr. Parsons adopted the extraordinary speed of revolution just named for the *Turbinia* he went far beyond all experience and precedent, and had to face unknown conditions. He has found the solution, after much patient and original investigation, in the use of multiple screws of small diameter. His results in this direction are of general interest to all who have to deal with screw propulsion. Such radical changes in propelling machinery as are involved in the adoption of turbo-motors must necessarily be subjected to thorough test before they will be widely adopted. The experiment which the Admiralty are making is not on a small scale as regards power. Although it is made in a destroyer, about 10,000 horsepower will probably be developed, and a cor-

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respondingly high speed attained. It may well happen that from this experiment very far-reaching effects may follow. Mr. Parsons himself has prepared many designs illustrating various applications of the system to seagoing, cross-channel and special service vessels. Where shallowness of draught is unavoidable, the small diameter of the screws possible with the quick-running turbines is clearly an important matter.

COMPARISONS BETWEEN LARGE AND SMALL VESSELS.

It has been shown that the attainment of very high speeds by vessels of small size involves many conditions not applicable to large seagoing steamships. But it is equally true that in many ways the trials of small, swift vessels constitute model experiments, from which interesting information may be obtained as to what would be involved in driving ships of large size at speeds much exceeding any of which we have experience. When the progressive steam trials of such small vessels can be studied side by side with experiments made on models to determine their resistance to various speeds, then the fullest information is obtained, and the best guide to progress secured. This advantage, as has been said, we owe to William Froude. His contributions to the "Reports" of the British Association are classics in the literature of the resistance and propulsion of ships. In 1874 he practically exhausted the subject of frictional resistance, so far as it is known, and his presidential address in 1875 dealt fully and lucidly with the modern or stream-line theory of resistance. No doubt there would be advantage in extending Froude's experiments on frictional resistance to greater lengths and to ship-shaped forms. It is probable, also, that dynamometric determinations of the resistance experienced by ships of modern forms and considerable size, when towed at various speeds, would be of value if they could be conducted.

These extensions of what Froude accomplished are not easily carried out, and in this country the pressure of work on shipbuilding for the Royal Navy has for many years past taxed to the utmost limits the capacity of the Admiralty experimental establishment, so ably superintended by Mr. R. E. Froude, allow-

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ing little scope for purely scientific investigations, and making it difficult to deal with the numerous experiments incidental to the designs of actual ships. Now that Holland, Russia, Italy and the United States have equipped experimental establishments, while Germany and France are taking steps in that direction, we may hope for extensions of purely scientific work and additions to our knowledge. In this direction, however, I am bound to say that much might be done if experimental establishments capable of dealing with questions of a general nature relating to resistance and propulsion were added to the equipment of some of our universities and colleges. Engineering laboratories have been multiplied, but there is as yet no example of a model experimental tank devoted to instruction and research.

It is impossible here to attempt any account of Froude's "scale of comparison" between ships and models at "corresponding speeds." But it may be of interest to give a few illustrations of the working of this method, in the form of a contrast between a destroyer of 300 tons, 212 feet long, capable of steaming 30 knots an hour, and a vessel of similar form enlarged to 765 feet in length and 14,100 tons. The ratio of dimensions is here about 3.61 : 1, the ratio of displacements is 47 : 1, and the ratio of corresponding speeds is 1.9:1. To 12 knots in the small vessel would correspond 22.8 knots in the large vessel, and the resistance experienced by the large vessel at 22.8 knots—neglecting a correction for friction—should be forty-seven times that of the small vessel at 12 knots. By experiment this resistance for the small vessel was found to be 1.8 tons. Hence, for the large vessel at 22.8 knots, the resistance should be 84.6 tons. This would correspond to an "effective horsepower" of over 13,000, or to about 26,000 indicated horsepower. The frictional correction would reduce this to about 25,000 horsepower, or about 1.8 horsepower per ton. Now, turning to the destroyer, it is found experimentally that at 22.8 knots she experiences a resistance of about eleven tons, corresponding to an effective horsepower of over 1,700 horsepower, and an indicated horsepower of about 3,000 horsepower; say, 10 horsepower per ton, or nearly five and a half times the power per ton required in

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the larger vessel. This illustrates the economy of propulsion arising from increased dimensions.

Applying the same process to a speed of 30 knots in the large ship, the corresponding speed in the small ship is 15.8 knots. Her resistance at that speed is experimentally determined to be 3.5 tons, and the resistance of the large ship at 30 knots neglecting frictional correction, is about 165 tons. The effective horsepower of the large ship at 30 knots is, therefore, about 34,000 horsepower, corresponding to 68,000 horsepower indicated. Allowing for the frictional correction, this would drop to about 62,000 horsepower, or 4.4 horsepower per ton. For the destroyer at 30 knots the resistance is about 17½ tons; the effective horsepower is 3,600 horsepower, and the indicated horsepower about 6,000 horsepower, or 20 horsepower per ton—nearly five times as great as the corresponding power for the large ship. But while the destroyer under her trial conditions actually reaches 30 knots, it is certain that in the large ship neither weight nor space could be found for machinery and boilers of the power required for 30 knots, and of the types usually adopted in large cruisers, in association with an adequate supply of fuel. The explanation of the methods by which the high speed is reached in the destroyer has already been given. Her propelling apparatus is about one-fourth as heavy in relation to its maximum power, and her load is only about one-third as great in relation to the displacement, when compared with the corresponding features of the cruiser.

The earlier theories of resistance assumed that the resistance experienced by ships varied as the square of the speed. We now know that the frictional resistances of clean, painted surfaces of considerable length vary as the 1.83 power of the speed. This seems a small difference, but it is sensible in its effects, causing a reduction of 32 per cent. at 10 knots, nearly 40 per cent. at 20 knots, and 42 per cent. at 25 knots. On the other hand, it is now known that the laws of variation of the residual or wave-making resistance may depart very widely from the law of the square of the speed, and it may be interesting to trace for the typical destroyers how the resistance actually varies. Take

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first, the total resistance. Up to 11 knots it varies nearly as the square of the speed; at 16 knots it has reached the cube; from 18 to 20 knots it varies as the 3.3 power. Then the index begins to diminish; at 22 knots it is 2.7; at 25 knots it has fallen to the square; and from there to 30 knots it varies practically as does the frictional resistance. The residual resistance varies as the square of the speed up to 11 knots; as the cube, at 12½ to 13 knots; as the fourth power, about 14½ knots; and at a higher rate than the fifth power at 18 knots. Then the index begins to fall, reaching the square at 24 knots, and falling still lower at higher speeds. It will be seen, therefore, that when this small vessel has been driven up to 24 or 25 knots by a large relative expenditure of power, further increments of speed are obtained with less proportionate additions to the power.

Passing from the destroyer to the cruiser of similar form but of 14,100 tons, and once more applying the scale of comparison, it will be seen that to 25 knots in the destroyer corresponds a speed of 47½ knots in the large vessel. In other words, the cruiser would not reach the condition where further increments of speed are obtained with comparatively moderate additions of power until she exceeded 47 knots, which is an impossible speed for such a vessel under existing conditions. The highest speeds that could be reached by the cruiser with propelling apparatus of the lightest type yet fitted in large seagoing ships would correspond to speeds in the destroyer, for which the resistance is varying as the highest power of the speed.

These are suggestive facts. Frictional resistance, as is well known, is a most important matter in all classes of ships and at all speeds. Even in the typical destroyer this is so. At 12 knots the friction, with clean, painted bottom, represents 80 per cent. of the total resistance; at 16 knots, 70 per cent.; at 20 knots, a little less than 50 per cent., and at 30 knots, 45 per cent. If the coefficient of friction were doubled, and the maximum power developed with equal efficiency, a loss of speed of fully 4 knots would result. In the cruiser of similar form the friction represents 90 per cent. at 12 knots, 85 per cent. at 16 knots, nearly 80 per cent. at 20 knots, and over 70 per cent. at 23 knots.

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If the coefficient of friction were doubled at 23 knots, and the corresponding power developed with equal efficiency, the loss of speed would approximate to 4 knots. These illustrations only confirm general experience that clean bottoms are essential to economical propulsion and the maintenance of speed, and that frequent docking is necessary in vessels with bare iron or steel skins which foul in a comparatively short time.

POSSIBILITIES OF FURTHER INCREASE IN SPEED.

From the facts above mentioned it is obvious that the increase in speed which has been effected is the result of many improvements, and has been accompanied by large additions to size, engine power and cost. These facts do not discourage the inventor, who finds a favorite field of operation in schemes for attaining speeds of 50 to 60 knots at sea in vessels of moderate size. Sometimes the key to this remarkable advance is found in devices for reducing surface friction by the use of wonderful lubricants to be applied to the wetted surfaces of ships, or by interposing a layer of air between the skins of ships and the surrounding water, or other departures from ordinary practice. If these gentlemen would "condescend to figures" their estimates or guesses would be less sanguine. In many cases the proposals made would fail to produce any sensible reduction in resistance; in others it would increase resistance. Other proposals rest upon the idea that resistance may be largely reduced by adopting novel forms, departing widely from ordinary ship shapes. Very often small-scale experiments, made in an unscientific and inaccurate manner, are adduced as proofs of the advantages claimed. In other instances mere assertion is thought sufficient. Ordinarily no regard is had to other considerations, such as internal capacity, structural weight and strength, stability and seaworthiness. Most of these proposals do not merit serious consideration. Any which seem worth investigation can be dealt with simply and effectively by the method of model experiments. A striking example of this method will be found in the usual form of a parliamentary paper—No. 313, of 1873—containing a report made by Mr. William Froude to the Ad-

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miralty. Those interested in the subject will find therein much matter of special interest in connection with the conditions attending abnormally high speeds. It must suffice now to say that ship-shaped forms are not likely to be superseded at present.

The most prolific inventions are those connected with supposed improvements in propellers. One constantly meets with schemes guaranteed by the proposers to give largely increased efficiency and corresponding additions to speed. Variations in the numbers and forms of screws or paddles, the use of jets of water or air expelled by special apparatus through suitable openings, the employment of explosives, imitations of the fins of fishes, and numberless other departures from established practice, are constantly being proposed. As a rule, the "inventors" have no intimate knowledge of the subject they treat, which is confessedly one of great difficulty. When experiments are adduced in support of proposals they are almost always found to be inconclusive and inaccurate. More or less mathematical demonstrations find favor with other inventors, but they are not more satisfactory than the experiments. An air of great precision commonly pervades the statements made as to possible increase in efficiency or speed. I have known cases where probable speeds with novel propellers have been estimated or guessed to the third place of decimals.

In one instance a trial was made with the new propeller, with the result that, instead of a gain in efficiency, there was a serious loss of speed. Very few of the proposals made have merit enough to be subjected to trial. None of them can possibly give the benefits claimed. It need hardly be added that, in speaking thus of so-called "inventors," there is no suggestion that improvement has reached its limit, or that further discovery is not to be made. On the contrary, in regard to the forms of ships and propellers, continuous investigation is proceeding and successive advances are being made. From the nature of the case, however, the difficulties to be surmounted increase as speeds rise; and a thorough mastery of the past history and present condition of the problems of steamship design and propulsion

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is required as a preparation for fruitful work in the nature of further advance.

It would be idle to attempt any predictions as to the characteristic features of ocean navigation sixty years hence. Radical changes may well be made within that period. Confining attention to the immediate future, it seems probable that the lines of advance which I have endeavored to indicate will remain in use. Further reductions may be anticipated in the weight of propelling apparatus and fuel in proportion to the power developed; further savings in the weight of the hulls, arising from the use of stronger materials and improved structural arrangements, improvements in form and enlargement in dimensions. If greater draughts of water can be made possible, so much the better for carrying power and speed. For merchant vessels commercial considerations must govern the final decision; for warships the needs of naval warfare will prevail.

It is certain that scientific methods of procedure and the use of model experiments on ships and propellers will become of increased importance. Already avenues for further progress are being opened. For example, the use of water-tube boilers in recent cruisers and battleships of the Royal Navy has resulted in saving one-third of the weight necessary with cylindrical boilers of the ordinary type to obtain the same power, with natural draft in the stokeholds. Differences of opinion prevail as to the policy of adopting particular types of water-tube boilers, but the weight of opinion is distinctly in favor of some type of water-tube boiler in association with the high steam pressures now in use. Greater safety, quicker steam raising and other advantages, as well as economy of weight, can thus be secured. Some types of water-tube boilers would give greater saving in weight than the particular type used in the foregoing comparison with cylindrical boilers. Differences of opinion prevail, also, as to the upper limit of steam pressure which can, with advantage, be used, taking into account all the conditions in both engines and boilers. From the nature of the case, increases in pressure beyond the 160 pounds to 180 pounds per square inch commonly reached with cylindrical boilers, can not have any-

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thing like the same effect upon economy of fuel as the corresponding increases have had, starting from a lower pressure. Some authorities do not favor any excess above 250 pounds per square inch on the boilers, others would go as high as 300 pounds, and some still higher.

Passing to the engine rooms, the use of higher steam pressures and greater rates of revolution may, and probably will, produce reductions in weight compared with power. The use of stronger materials, improved designs, better balance of the moving parts and close attention to details have tended in the same direction without sacrifice of strength. Necessarily there must be a sufficient margin to secure both strength and endurance in the motive power of steamships. Existing arrangements are the outgrowth of large experience, and new departures must be carefully scrutinized. The use of rotary engines, of which Mr. Parsons' turbomotor is the leading example at present, gives the prospect of still further economies of weight. Mr. Parsons is disposed to think that he could about halve the weights now required for the engines, shafting and propellers of an Atlantic liner, while securing proper strength and durability. If this could be done in association with the use of water-tube boilers it would effect a revolution in the design of this class of vessel, permitting higher speeds to be reached without exceeding the dimensions of existing ships. It does not appear probable that, with coal as the fuel, water-tube boilers will surpass in economy the cylindrical boilers now in use; and skilled stoking seems essential if water-tube boilers are to be equal to the other type in rate of coal consumption. The general principle holds good that as more perfect mechanical appliances are introduced, so more skilled and disciplined management is required in order that the full benefits may be obtained. In all steamship performance the "human factor" is of great importance, but its importance increases as the appliances become more complex. In engine rooms the fact has been recognized and the want met. There is no reason why it should not be similarly dealt with in the boiler rooms.

Liquid fuel is already substituted for coal in many steamships. When sufficient quantities can be obtained, it has many obvious

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advantages over coal, reducing greatly manual labor in embarking supplies, conveying it to the boilers, and using it as fuel. Possibly its advocates have claimed for it greater economical advantages over coal than can be supported by the results of extended experiment. Even if the saving in weight for equal evaporation is put as low as 30 per cent. of the corresponding weight of coal, it would amount to 1,000 tons on a first-class Atlantic liner. This saving might be utilized in greater power and higher speed, or in increased load. There would be a substantial saving on the stokehold staff. At present it does not appear that adequate supplies of liquid fuel are available. Competent authorities here and abroad are giving attention to this question, and to the development of supplies. If the want can be met at prices justifying the use of liquid fuel, there will undoubtedly be a movement in that direction.

Stronger materials for the construction of hulls are already available. They are, however, as yet but little used, except for special classes of vessels. Mild steel has taken the place of iron, and effected considerable savings of weight. Alloys of steel with nickel and other metals are now made, which give strength and rigidity much superior to mild steel, in association with ample ductility. For destroyers and torpedo boats this stronger material is now largely used. It has also been adopted for certain important parts of the structures of recent ships in the Royal Navy. Of course, the stronger material is more costly, but its use enables sensible economies of weight to be made. It has been estimated, for example, that in an Atlantic liner of 20 knots average speed about 1,000 tons could be saved by using nickel-steel instead of mild steel. This saving would suffice to raise the average speed more than a knot, without varying the dimensions of the ship. Alloys of aluminum have also been used for the hulls or portions of the hulls of yachts, torpedo boats and small vessels. Considerable savings in weight have thus been effected. On the other hand, these alloys have been seriously corroded when exposed to the action of sea water, and on that account are not likely to be extensively used. Other alloys will probably be found which will be free from this defect, and yet unite lightness with strength to a remarkable degree.

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Other examples might be given of the fact that the metallurgist has by no means exhausted his resources, and that the shipbuilder may look to him for continued help in the struggle to reduce the weights of floating structures.

It is unnecessary to amplify what has already been said as to possible increase in the efficiency and types of propellers. With limited draught, as speeds increase and greater powers have to be utilized, multiple propellers will probably come into use. Mr. Parsons has shown how such problems may be dealt with; and other investigators have done valuable work in the same direction. In view of what has happened, and is still happening, it is practically certain that the dimensions of steamships have not yet attained a maximum. Thanks to mechanical appliances, the largest ships built, or to be built, can be readily steered and worked. In this particular difficulties have diminished in recent years, notwithstanding the great growth in dimensions. Increase in length and weight favor the better maintenance of speed at sea. The tendency, therefore, will be to even greater regularity of service than at present. Quicker passages will to some extent diminish risks, and the chance of breakdown will be lessened if multiple propellers are used. Even now, with twin screws, the risk of total breakdown is extremely small.

Whatever may be the size and power of steamships, there must come times at sea when they must slow down and wait for better weather. But the larger and longer the vessel, the fewer will be the occasions when this precaution need be exercised. It must never be forgotten that as ships grow in size, speeds and cost, so the responsibilities of those in charge increase. The captain of a modern steamship needs remarkable qualities to perform his multifarious duties efficiently. The chief engineer must have great powers of organization, as well as good technical knowledge, to control and utilize most advantageously the men and machinery in his charge. Apart from the ceaseless care, watchfulness and skill of officers and men, the finest ships and most perfect machinery are of little avail.

The "human factor" is often forgotten, but is all-important. Let us hope that in the future, as in the past, as responsibilities increase so will the men be found to bear them!

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COATINGS FOR CAST-IRON WATER PIPES.*

By Thomas H. Wiggin.

It is probable that nearly every engineer who has had a large number of pipes to lay has resolved that he will do something to dispel the mist that hangs about the subject of preservative coatings. Very many seem to have made concoctions of coal tar, asphalt, linseed oil and other things, in the endeavor to strike the fortuitous combination of cheap products which would adequately protect the metal. If all these experiments could be published the engineering world might finally arrive at a choice by rejection. As it is, the same ground is covered several times over with the same disappointing results. The question of preservative coatings belongs properly to the skilled chemist, but it has been attacked with some assurance by persons (including the writer) who are not chemists. The results of the writer's observation, study and experiment, made in connection with the Metropolitan Water Works, will be given.

COAL-TAR COATING.

The inspector having passed judgment on the pipes, they are rolled along down to the coating apparatus. The apparatus consists of a number of ovens, with iron cars, on which the pipes are rolled into the oven and on which they stand during heating, a vat or tank for the coating compound, a crane for hoisting the pipes in and out of the vat, and various brushes, scrapers and mops for brushing out dirt and removing surplus coating material. The coating material is crude gas tar with sometimes some dead oil of tar added. The pipes are given a fairly good brushing before being put in the oven. The oven is

* Extracted from a paper on "The Manufacture and Inspection of Cast-Iron Pipes," read before the Boston Society of Civil Engineers.

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merely an enlarged chimney flue, for all the smoke and gases of combustion pass in at one part and out at another, so that a light, but visible deposit of soot is made on the pipes, which is not brushed off. The old-fashioned ovens have simply a square hole through the floor of the oven connecting it with the fire, so that the hot gases, and occasionally flame, act principally upon one portion of the pipe, heating that portion very hot before materially affecting the other portions. The newer ovens are fitted with an arched bottom, with bricks left out at intervals all along the pipe, this arrangement causing a more uniform temperature. The pipe is left in the oven until the attendants think (no thermometer is used) it is heated to about the correct temperature (48-inch pipes are left in about 20 minutes); then it is put in the tar to stay from a moment to 10 minutes, according to the condition of the work about the vat. On being removed from the vat, the pipe is allowed to drain over the vat, and the drainage is aided by scraping the invert with a segmental hoe, made to fit, or at least to be of smaller radius, than the pipe. The pipe is then lifted out on to skids and the coating smoothed up further —surplus tar removed and thin places reinfored—by a brush or a mop. The brush is better, because the mop leaves part of itself behind on each pipe. The coating becomes hard in from one-half to two hours, according to conditions.

Coal tar is a very complex mixture; indeed, the fact is so well known that people are not seldom heard calling a doubtful drug "one of those coal-tar products." Moreover, coal tar varies very widely according to the coal used and the temperature maintained in the manufacture of the gas. Furthermore, crude tar varies at different heights in the tank in which it is collected at the gas works. But no tests are made to obtain any particular kind of tar for coatings. The unrefined overflow from the hydraulic main of the gas plants is purchased where it can be obtained easiest and cheapest. Specifications often call for deodorized tar, but the most noticeable thing about coating tar is its dense and pungent fumes when heated.

The degree of the fluidity of the tar varies with the composition and with the temperature. In summer tar is usually more

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fluid than molasses; in winter it has often to be melted out of the barrels. This crude tar cannot be used as a paint for cold surfaces, because it will not harden. Tar from the coating vat, though always somewhat refined by the continued heating, does not harden sufficiently when applied to cold surfaces. This suggests the philosophy of the whole tar process of coating. By the heat of the pipes the tar is distilled down to a compound which is solid at atmospheric temperatures. A very favorable condition for this volatilization of the liquefying constituents (which are also the most volatile constituents) evidently exists when the tar is exposed to the air, spread, as it is then, in a thin film over the hot pipes; and that rapid volatilization takes place at this time is indicated by the dense fumes given off.

As a corollary to the foregoing, it follows that the temperature of the pipe, as it emerges from the tar bath, is one vital factor in the character of the coating. If the pipe is too hot, the coating is over-distilled and becomes too brittle, or may even be reduced to an earthy, carbonaceous residuum. If the pipe is too cool, a thicker coating is formed, which will not harden sufficiently, will come off in the skids and will run in warm weather. Thin pipes must be heated hotter than thick pipes, because the thin metal does not hold the heat so long, and hence the distillation must be more rapid at first. The writer made an attempt to measure the temperature of some pipes just before they were dipped. An ordinary thermometer was, of course, of no use, nor could an electrical device be found which experts would recommend to record such low temperatures. Hence, the writer procured several chemicals which are said to pass through noticeable changes at certain fixed temperatures: red iodide of mercury, which is said to change to the yellow at about 300 degrees Fahrenheit; yellow stick sulphur, which fuses at about 235 degrees Fahrenheit, and silver nitrate, which fuses at 424 degrees Fahrenheit. Every pipe which was tried turned the red mercuric iodide to the yellow form, but no pipe, apparently, fused the silver nitrate. The effect on the latter and on the sulphur was hard to observe on account of the heat and smoke; hence, the only conclusion that could safely be drawn was that

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pipes, just before coating, are usually considerably over 300 degrees Fahrenheit. With tar and thickness of pipe so variable, the proper temperature must be a matter of judgment on the part of the dipman. A reliable and handy pyrometer would help, however, as it would enable the dipman to use the experience gained on one pipe in judging of the next one.

There is no question about the importance of having ovens properly arranged to heat the pipes uniformly. The brick fire arch, having bricks left out at intervals all along the position of the pipe, is rather satisfactory. The single opening at one end of the pipe is decidedly unsatisfactory. The soot that is deposited on the pipes may do some harm. More elaborate and more nearly perfect schemes for heating pipes will quickly suggest themselves, but it seems probable that a careful application of the present methods will give results as satisfactory as a crude tar coating warrants. Careless application will vitiate any method. Thus, at one foundry the pipes are often wittingly underheated on days when strong northerly winds prevail, because the wind makes it difficult to heat the ovens, and the day's work must be done just the same. Again, the pipes which stay in the oven during the dinner half hour are liable to go into the tank too hot, because they are left in the oven too long and are not allowed to cool down. In general, the men fall into a certain routine of work—so many pipes to brush out, so many to mop out, so many to roll into the oven, etc., between dippings, and this routine fixes the time of heating. A good dipman will not allow very noticeable errors in temperatures to pass, but he will not delay the routine for minor errors. In other words, the application of the method is inferior to the best judgment of the dipman.

The character of the tar in the bath is another important variable. New tar gives softer coatings, other things equal, because it contains more of the lighter constituents. Thick tar gives thicker coatings than thin tar. The temperature of the pipe should be varied to meet variations in the coating compound. Fresh tar requires a hotter pipe than does old tar. Regularity in aiding new tar would give greater uniformity in coatings, but

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tar is often not in stock when it is needed, and the dipman does not care much, so long as the coating passes—and the inspectors do not usually pretend to know much about coatings or to judge them very harshly.

The temperature of the tar itself does not count for much when the pipes are heated before being dipped, as is universal now. In the old method of heating the pipes by allowing them to remain in the dip half an hour or so, the temperature of the dip was very important, though less so than it would have been with crude tar. The temperature of the tar in the present method is usually about 220 to 230 degrees Fahrenheit. Observations of men at the foundry on temperature of the dip, and the writer's observations on small quantities of tar, indicate that new tar, on account of the lighter constituents,* does not at first rise above 220 degrees Fahrenheit. Later it rises to 350 degrees Fahrenheit, if heated sufficiently. It is evident that the old method of allowing the pipes to come to their proper temperature in the dip would lead into difficulty if the crude tar was fresh in the tank, as it would be difficult or impossible to raise the pipes to the required 300 degrees or more.

Small pipes are, as a rule, carelessly heated, and the writer has often seen very hot pipes lowered into the tank, where they caused a violent boiling and much yellow smoke (yellow smoke is the founder's sign of an excessively hot pipe). An inspector said that at one foundry pipes hot enough to set fire to the tar are so common that lids are rigged so that they can be rapidly unhooked and allowed to fall over the tank and smother the flames.

DEAD OIL.

Specifications often call for the use of dead oil of coal tar in the dip. Dead oil is defined as that part of coal tar which is obtained, in fractional distillation of coal tar, between the temperatures of 410 and 750 degrees Fahrenheit, approximately. It

* The law of fractional distillation is that a mixture, when distilled, remains at the boiling temperature of that constituent which boils at the lowest temperature until that constituent is gone; then rises to the next lowest boiling point and remains there, and so on.

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contains both the creosote and the anthracene oils. Whether the commercial article agrees with this definition is unknown to the writer.

Some commercial dead oil that the writer tried evaporated about one-seventh as rapidly as water, both being exposed to the air. A brown cake was left in the bottom of the vessel. The misconception is probably often entertained that dead oil bears to tar coating a relation similar to that of linseed oil to paint. A better comparison would be that between dead oil in coal tar and turpentine in paint. Dead oil is of use principally to thin back the tar when it becomes thicker than the dipman likes it. Ordinarily, the necessary adding of fresh tar is sufficient to keep the tar thin. At one foundry no dead oil would ever be used if the engineer did not occasionally require it. At another foundry it is the regular practice to use one barrel of dead oil to about seven of coal tar. A change was made at one foundry from no dead oil to about the above proportions, but it had no visible effect on the character of the coating. The effect on the composition of the tar dip was to increase the proportion of the heavy oils in the tar from about 25 to about 35 per cent., and perhaps the change really did improve the coating.

TAR AND LINSEED OIL.

The use of linseed oil in tar coatings dates back to the first tar coating of Dr. Robert Angus Smith, a patent for which was taken out in Great Britain in 1848. The patent states that pipes were first to be cleaned and then preferably coated with linseed oil. Pipes might be heated before dipping, or allowed to come to a heat in the mixture. The tar was distilled to "a thick, pitch-like mass," and kept at a temperature of about 300 degrees Fahrenheit. Pipes were left in the dip about thirty minutes. Dr. Smith found it "desirable to pour a quantity of linseed oil on the coated surfaces," which process had "the effect of removing any excess of tar, and the oil running into the tar kept it fluid and prevented its becoming unsuitable for further use." Such was the first coating of Dr. Smith. The writer found several different coatings described as Dr. Smith's, and it is probable that the

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doctor improved on his original one. The foundrymen to-day often call the crude-tar coating in present use "the ordinary Angus Smith coating." In "Water Supply of Cities and Towns," by William Humber (1876), two methods used by Dr. Smith are given. In both the dip contained gas tar, Burgundy pitch, oil and resin, the percentage of linseed oil in the second method being five or six. In the first of these methods the pipes were heated to from 400 to 500 degrees Fahrenheit, and the dip also was kept hot. In the second, the dip only was heated, and the pipes were allowed to take the temperature (300 degrees Fahrenheit) of the dip. It was supposed that the pores of the iron opened to receive the tar.

The questions that concern us now are whether linseed oil improves the quality of tar coating, and, if so, what method can be adopted for its use. On the first question we seem, as usual, to have no direct evidence. Old foundrymen will say that the present coating is not so good as the former coating was, but there are no comparative records available, so far as the writer knows. The writer has been unable to find out from records, or by questioning foundrymen, how much and in what ways linseed oil was used in the past, and when it ceased to be used. One very intelligent employee, who had been in the foundry business for about twenty years, thought there had been no linseed oil used at the foundries around Philadelphia since about 1872. Specifications throw little light on the subject, as they often contain directions that are not followed. It seems probable that the practice of using linseed was gradually dropped, perhaps on account of a change in the character of the tar obtained from the gas works, perhaps for other reasons of convenience; perhaps with the knowledge and consent of engineers, and perhaps without their knowledge. At any rate, the comfortable feeling of a question pretty well solved has continued; though perhaps, if the truth were known, the modern crude-tar coating would be found to be living on the hardearned reputation of the linseed oil coating. If records of the composition and behavior of coatings had been carefully kept and made available to students of the subject, many years of experience, now of little use, would have

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been saved to the world; and unless more care is taken, the next generation will make the same complaint.

In default of sufficient experience, we must resort to theory. The japan coating of Edward Smith & Co. is the result of careful theorization,* and the pamphlets issued by that firm containing articles by Mr. A. H. Sabin, chemist for the firm, and by others, give many facts in regard to preservative coatings. Mr. Sabin puts up a very strong plea for linseed oil, but he discards coal tar as a filler, and accepts copals and also asphalt, which chemists usually consider as a more enduring compound than the complex and volatile coal tar. Mr. Sabin is also enabled to use a large percentage of linseed, and without any injurious dryer, because he bakes his coating. Now, whether or not the asphalt is better than tar, the arguments brought forth for the use of linseed seem pretty strong, and the writer would make use of them to give some evidence that linseed oil would improve coal-tar coating.

Assuming, at any rate, that linseed oil would improve tar coating, the writer attempted to find out how it could be successfully applied to the present practice. At the McNeal foundry an experiment had just been tried with an imported English tar and raw linseed, the fact that crude American tar could not be used with linseed having been proved at this foundry in previous years. The English tar was said to be somewhat refined, but appeared about the same as the American crude tar. The tar pit was cleaned out and English tar and raw linseed, in the proportions of ten tar to one linseed, were put in. The mixture became thick and lumpy, and all efforts to make a passably smooth coating failed. Even a temperature of 350 degrees Fahrenheit failed to improve matters, and pipes had to be recoated. No more linseed was added to the dip, but fresh tar and dead oil were added as needed, so that the proportions of linseed steadily grew less. Finally the tank was cleaned out and the use of crude American tar resumed.

The following is a description of some of the experiments tried by the writer with tar and linseed: The mixtures were

* Also of much experience, though not with conditions such as exist in water pipes.

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made mostly in ten-quart porcelain-lined kettles. The specimens coated were fragments of pipes, the pieces being usually about 3 to 5 inches wide and 0.5 to 1.25 inches thick.

(1) Twenty-eight parts of English tar and one part of raw linseed. The linseed, cold, was added to the tar at 240 degrees Fahrenheit. Violent frothing took place. The mixture soon doubled its volume and ran over. Coating out of the question for practical use on account of frothing and lumpiness.

(2) Twenty-eight parts English tar, plus three parts raw linseed that had been boiled for ten minutes. Ingredients mixed with tar cold and brought to liquid state at about 340 degrees Fahrenheit.* Less frothing than before, but coating useless. Soft oil collected next the iron, and dull, earthy tar outside. Dead oil helped matters somewhat, but coating remained useless.

(3) Twenty-eight parts English tar, plus one part commercial boiled linseed (guaranteed by an acquaintance as not having been boiled "through the bung-hole"). At 230 degrees Fahrenheit violent frothing occurred, and, though a fairly good coating was obtained on a small scale, the method is out of the question for regular work. Dead oil did not help.

The foregoing experiments indicated that such crude tar could not be used.

(4) In order to get tar at least somewhat refined, took 4 quarts of tar from the coating tank. Added ¼ quart of boiled linseed oil thereto. Frothing was too vigorous for any thought of practical application.

(5) Boiled some crude tar for about 5½ hours. At the start, the tar was a thin fluid at atmospheric temperature. After boiling, the tar was a soft solid at atmospheric temperature. During boiling, the temperature of the tar remained at about 220 degrees Fahrenheit for about an hour, then rose to about 290 degrees and stayed there for a time, and finally became about 350 degrees.

To sixteen parts of this boiled tar, added one part of boiled linseed. No frothing occurred, even at 400 degrees Fahrenheit.

* This temperature seems abnormally high in view of the other results.

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The mixture was thick and did not harden sufficiently on fragments of ½-inch pipes. Later it occurred to the writer to try thick pipes (an inch or more thick), and there was no difficulty in getting the coating even too hard. No frothing occurred when dead oil was added to thin the mixture.

The experiment showed that linseed oil could be used with partially refined tar, but it also indicated that the application of the method required more intelligent care than does the crude-tar method.

Since making these experiments, the writer has found an old specification for tar coating, the method of which agrees so closely with the results of these experiments that the following quotation is made.* "The varnish, or pitch, is to be made from coal tar, distilled until all the naphtha is removed, the material deodorized and the pitch reduced to about the consistency of wax or very thick molasses. At least 8 per cent. of heavy linseed oil must be added." It is rather humiliating to come back to the results of thirty years ago. It would not be so if the old method had been deliberately abandoned for a better one; but, as already intimated, it is not apparent that such was the case.

Refined tar is now out of the market, though a tar residuum or pitch is used in roofing and for walks. As the above experiment indicates, it would be an easy matter to make some refined tar.

Procured some of the roofing pitch mentioned above. It is a solid, just viscous enough to slowly find its level in warm weather, but hard and brittle in cold weather.

(6) Roofing pitch alone. Coating was thick and very glossy, but, of course, rather brittle. Such a coating might give excellent results if handled only in warm weather, but would probably fly off in cold. This coating has stood water tests for about a couple of years without losing its smoothness and luster.

(7) Nine parts of roofing pitch and one of boiled linseed. A thick, glossy coating, not so brittle as pitch alone.

(8) Nine parts pitch to two boiled linseed. Better than seven as regards brittleness.

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* See Report of the Cochituate Water Board, 1867–68, p. 17.

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(9) Nine parts pitch to three boiled linseed. Coating more bulky and less smooth than the others.

A greater proportion of the linseed would make the coating like paint, and drying would be too slow, unless baking were resorted to, as in the Sabin japan.

ASPHALT COATINGS.

It is truly charged against coal tar that it continues to decompose, so that finally nothing but a friable, earthy pitch is left. It is said to be characteristic of pyrogenic (fire-formed) compounds, to which class coal tar belongs, that they are unstable at ordinary temperatures. Asphalt also decomposes with exposure, as demonstrated at the natural asphalt lakes, but, nevertheless, is thought to be more durabe than coal tar. The only direct long-time comparisons that occur to the writer are in the matter of walks and pavements, and here there is no doubt that the asphalt has demonstrated its superior durability. However, the conditions in a water pipe are different from those of a street surface; moreover, a coating material might be very durable in itself and yet not form an impervious coating, as is the case with pure linseed oil used alone. Asphalt has not the aggressive penetration of coal tar, nor does it stick to things and cover everything so persistently as tar. A little drop of tar will smirch skin, clothes, paper and everything that comes near it, without apparent diminution in size, while asphalt can be handled with impunity.

The usefulness of asphalt as a pipe-coating compound for cast iron has never been demonstrated, though asphalt has been, and is still, used largely in coating steel pipes. Some information on its success for steel pipes should be available by this time, but little has been published.

The writer tried many experiments with Alcatraz, or California asphalt. Grades of several degrees of hardness are made, and by mixing grades it is comparatively easy to get a good consistency. A temperature of about 260 degrees Fahrenheit was needed. The coating is not brittle, not very smooth, rather dull and not very tenacious. In fact, the impressions of the coating

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were rather of a negative nature. There were no glaring defects in the coating, neither was it very attractive.

Linseed mixes well with asphalt, but the coating does not harden unless a hard grade of asphalt is used.

P. & B. PIPE DIP.

This is a patent dip manufactured by the Standard Paint Company. Its principal ingredients probably are asphalt and candle-tar pitch. The latter is a pitch obtained by distillation of animal fats. This coating has been used somewhat on steel pipes, but not long enough for a test of durability. As applied to cast iron it gives a coating very similar to asphalt coating—not hard, not brittle, not very glossy, not very tenacious.

MINERAL RUBBER DIP.

This is a dip manufactured by the Assyrian Asphalt Company. The process is not patented, but is secret. The appearance indicates that the compound is largely asphalt, and the coating is somewhat similar to asphalt coating, only duller in appearance. The dip requires a temperature of about 400 degrees Fahrenheit. This dip has recently become very popular for steel pipes.

VARNISHES.

There are many cheap varnishes made from tar, and there are also more expensive ones containing asphalt and other ingredients. These varnishes consist of some solid dissolved in a volatile carrier, which quickly evaporates, leaving the solid on the coated body. The engineers of the Metropolitan Water Works have used a number of these varnishes in painting over the coal-tar coating, with the idea of filling up the pores in the coating. The writer has experimented with some of these varnishes.

(1) P. & B. Universal Paint, manufactured by the Standard Paint Company. This is to many a very familiar varnish, because it is not forgotten after having been once used. The solvent contains carbon disulphide, the odor of which is sickening to

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most persons. The coating seems fairly good after it is on, but the odor interferes with its use.

(2) P. & B. Ruberine, also manufactured by the Standard Paint Company. This varnish consists of "ruberoid" dissolved in naphtha. Ruberoid consists of California asphalt and candle-tar pitch digested and vulcanized with sulphur. Ruberine dries rapidly and is hard to spread smoothly. It gives, however, a substantial rubbery coating.

(3) Tar varnishes. Two of these were tried, one an American and the other a Dutch product, imported by Paul A. Davis, of Philadelphia, and said to be much used abroad. The varnishes were thin, had the coal-tar penetration, and gave smooth, good-looking coatings.

It is evident that the use of varnishes would be very limited, unless it were found possible to use them as dips; their rapid evaporation seems to preclude their use in this way; but trial alone, and on a large scale, would settle this question.

TESTS OF COATINGS.

Of course, the only satisfactory test of coatings is actual use under known conditions. Small-scale experiments are often misleading and always inconclusive. Moreover, all coatings are so durable that it takes a number of years to form an idea of their relative value, and by that time something new is often favored on theoretical evidence. However, the small specimens used in the experiments above described were subjected to several tests.

(1) Test for brittleness. Most of the specimens were tested by hammering to see whether the coating was liable to fly off in handling of pipes. Allusion to brittleness has been made in describing the coatings.

(2) Test of porosity. It is known that tubercles start at minute holes in coating. It was thought that if acid did not injure the coating material itself, it would give a test of the porosity of coatings by attacking the metal through the pores. Specimens of coated iron were put in glass jars containing a mixture of one part muriatic acid and two parts water. At the same time samples of the coating materials alone were put into other glass jars

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with acid of the same strength. Great activity was immediately apparent in the case of the coated iron, and a disagreeable gas with a sweetish odor was evolved. The coating materials alone, on the other hand, were apparently not acted upon. Their appearance, and the appearance of the acid in which they were submerged, remained the same to the end of the test, which was almost as long as the test of the coated iron.

The coatings were all badly undermined, and all but a specimen of Sabin's japan peeled off in many places. The iron was dissolved to a depth of $\frac{1}{8}$ inch in places, especially at the corners. The estimate that was placed upon the specimens, beginning with the least injured, is shown by Table I.

TABLE I.—ACID TESTS OF COATINGS FOR POROSITY.

	Coating.	Time exposed, days.	Remarks.
1.	Sabin Japan	55	Specimen said to have been rusty before being coated.
2.	Crude tar	55	.....
3.	Tar and linseed	60	No distinction possible.
	Alcatraz asphalt, pitch and linseed	60	
	Mineral dip (Assyrian Asphalt Co.)	55	
	P. & B. dip (Standard Paint Co.)	55	
4.	Alcatraz asphalt	55	.....
5.	All the varnishes	55	Totally destroyed.

There was only one specimen of each coating.

(3) Running-water test. The specimens indicated in Table II have been kept in running Boston water. Many tubercles have already formed on corners and on the rough fractured edges, but only a few* on the smooth large faces that formed parts of the inside and outside, respectively, of the pipes from which the specimens of iron were broken. The writer's estimate of the coatings is given in Table II.

* This does not include the numerous tubercles, due perhaps to galvanic action, that were formed at many places along the copper wire wound around the specimens to suspend them by.

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TABLE II.—RESULTS OF EXPOSING COATINGS TO RUNNING WATER.

Coating.	Time exposed, years.	Remarks.
1. Tar and linseed.....	2	Coating is smooth and in good condition, except for group of five ¼-inch tubercles.
2. Mineral dip.....	2	Few tubercles on large surfaces, but coatings rather earthy.
P. & B. dip.....	2	
3. Alcatraz asphalt.....	2	Badly tubercled; covered with crumbling blisters.

There was only one specimen of each coating.

The samples indicated in Table III have endured four months in running Delaware River water, whereby they were scarcely tubercled at all, but received a heavy coat of mud washings to remove the mud, and finally seventeen months in running Boston water, where they still are. The specimens have only three to five incipient tubercles* and a few specks on the large surfaces, though there are a good many well-developed tubercles, as usual, on the rough edges of fracture, and around the copper suspension wire. In general appearance the writer would rank them as is Table III.

TABLE III.—RESULTS OF EXPOSING COATINGS TO RUNNING DELAWARE RIVER WATER FOR FOUR, AND BOSTON WATER FOR SEVENTEEN MONTHS.

Coating.	Remarks.
1. Pitch.....	Coating still glossy.
2. Pitch and linseed.....	
3. Pitch and linseed, painted with Dutch varnish.	
4. Mineral dip.....	Tubercles not more numerous than in the case of the foregoing specimens; surfaces rather earthy in appearance, and not smooth.
P. & B. dip.....	
5. Dutch varnish.....	Freer from tubercles than any of the other specimens; surface is earthy and friable, black powder being easily scraped off.

There was only one specimen of each coating.

*A piece of pottery coated with Dutch varnish was not tubercled at all. This corresponds with the generally accepted idea that iron is essential to the formation of tubercles.

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The specimens in Table IV, endured the same treatment in Delaware water and subsequent washing off of mud, and were finally placed in a tank of water that is not often changed, where they have been about fifteen months. The tank has been used for much of the time for cement briquettes, and the water is hence very alkaline.

TABLE IV.—RESULTS OF EXPOSING COATINGS FIRST TO RUNNING WATER AND THEN TO ALKALINE WATER, SELDOM CHANGED.

	Coating.	Remarks.
1.	Pitch	Good condition; few tubercles.
2.	Tar covered with Dutch varnish	
3.	Tar and linseed	
4.	Alcatraz asphalt, pitch and linseed	
	Tar	
5.	Mineral dip	In fair condition.
	Alcatraz asphalt and linseed (two specimens)	
	Alcatraz asphalt, pitch and linseed (specimen)	
	P. & B. paint (two specimens)	Few tubercles; coatings rather earthy; black will rub off.
	Dutch varnish	
6.	Mineral dip (another specimen)	Bad condition; many well-developed tubercles; also crumbling blisters.
	P. & B. dip	
	Alcatraz (two specimens)	

There was only one specimen of each coating, except in the cases specially noted above.

TABLE V.—APPROXIMATE RELATIVE COST OF VARIOUS COATINGS.

Coating.	Approximate amount required to coat one 48-inch pipe.	Approximate price.	Cost of material, one 48-in. pipe.
Crude tar	3¾ gallons.*	$3.00 per bbl. (52 galls.)	$ .22
Pitch	5 "	5.00 " " "	.50
Pitch and linseed	.....	.....	.70
P. & B. dip	20 pounds.	$45.00 per ton.	.45
Mineral dip	20 "	75.00 " "	.75
P. & B. Univ. paint	1½ gallons.	1.00 per gallon.	1.50 †
P. & B. ruberine	1½ "	1.00 " "	1.50 †
Tar varnish	1½ "	.10 " "	.15 †
Dutch varnish	1½ "	.25 " "	.40 †
Sabin japan	1½ "	1.75 " "	2.60 ‡

*About 30 per cent. of this lost by evaporation.

† Estimated cost of the coating applied as by a brush. Wastage might be excessive as dip, but the latter would be the only practical way for use on a large scale; hence the figures above are not strictly to the point.

‡ This coating requires a comparatively expensive plant and considerable skilled labor, which would largely increase the total cost.

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Table V gives a very rough idea of the relative cost of the various coating materials. The crude tar results are based on actual records and are believed to be reasonably close. The other results are mere estimates, based, in the case of the dips, on the results for tar; in the case of the varnishes on estimated covering capacity; and in the case of the Sabin japan on results for steel pipes.

CONCLUSIONS.

Should the Sabin japan prove by use to be as good as it appears to be, engineers would have to decide whether it were economical to add from 5 to 10 per cent. to the cost of pipes in order to prevent in part a deterioration, in the carrying capacity, which has been found as large as 20 per cent. in 16 years in even large pipes.* But the efficacy of the coating must be proved by several years of use.

As for the above tests, the tar compounds seem to have the best of them on the whole (barring the Sabin japan, which was tested only by acid), though the tests are too few and too short to serve as a basis for decided opinions. The writer would like to try roofing pitch on some pipes. He has considerable faith in the efficacy of thick, smooth coatings, such as it makes. The experiments show that only a thick coating will protect rough surfaces and corners. If the pitch proved too brittle to stand the handling of shipping and carting, it would not be impossible to have a portable coating outfit. The writer would also like to see a refined-tar and linseed-oil coating tried on the commercial scale. He would suggest that it would not be a very expensive experiment for a large city to try the several coatings on some line of its pipes and thus determine in a national way what coating was best for its water.

Rusty pipes will apparently not hold a coating. At one foundry were several 30-inch pipes having only little blotches of tar coating left on them. The writer was told that these pipes were coated only two years before, but were very rusty when coated.

* See paper by Desmond FitzGerald, Mem. Am. Soc. C. E., Trans. of Am. Soc. C. E., Vol. XXXV, 1896, p. 241.

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The foundry scale which forms the surface of castings will protect the castings from rust for some time. Even when a casting is allowed to stand in a shower or two, only streaks of rust on top are formed at first. All chipped surfaces, however, quickly rust, and it is noticeable that coating over chipped surfaces is often quickly destroyed. Whether this is due to the surface being rusty before coating, or to a poor adhesion of the coating to even clean chipped surfaces, is unknown to the writer.

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THE THERMAL EFFICIENCY OF STEAM ENGINES.

One of the most important engineering papers published in recent years was the report of the committee appointed by the Institution of Civil Engineers to consider and report to the council upon the subject of the definition of a standard or standards of thermal efficiency for steam engines. We print the main portion below as given in the Proceedings of the above society.—ED.

INTRODUCTORY NOTE.—PREPARED AT THE REQUEST OF THE COUNCIL, BY CAPTAIN SANKEY.

The following report assumes a competent knowledge of thermo-dynamics, and some explanation may therefore be of use to those who have not this knowledge, but yet are interested in steam-engine economy. For this purpose the following introductory note has been drawn up to show what it has been desired to measure and to compare.

A steam plant in its simplest form normally consists of:

(1) The boiler, with its feed arrangements, to produce the steam.

(2) The pipes to conduct the steam to the engine.

(3) The engine to transform a portion of the steam energy into work upon the pistons.

Further the plant may include:

(4) A condenser with an air pump or equivalent apparatus, which must be added if the engine is to be relieved from the back pressure due to the atmosphere.

(5) An economizer may be added to the boiler to improve its performance by transmitting to the feed water some of the heat which would otherwise escape up the flue.

(6) A feed heater may be used in the case of a non-condensing engine, to recover some of the waste heat in the exhaust steam.

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(7) Steam jackets and reheaters are added to the engine under certain circumstances.

No portion of a steam plant is perfect, and each is the seat of losses more or less serious. If, therefore, it is desired to improve the steam plant as a whole, it is first of all necessary to ascertain separately the nature of the losses due to its various portions; and in this connection the diagrams in Plate 5 have been prepared, which it is hoped may assist to a clearer understanding of the nature and extent of the various losses.

The boiler, the engine, the condenser and air pump, the feed pump and the economizer, are indicated by rectangles upon the diagram. The flow of heat is shown as a stream, the width of which gives the amount of heat entering and leaving each part of the plant per unit of time; the losses are shown by the many waste branches of the stream. Special attention is called to the one (unfortunately small) branch which represents the work done upon the pistons of the engine.

It is obvious that with so many channels of loss, it is of the utmost importance that the circumstances under which they arise, and their amount, should be ascertained and considered separately. It is also especially useful to ascertain the exact amount of those losses which are inevitable according to the laws of Nature, and to distinguish them from other losses, also to some extent inevitable but yet capable of reduction by improvement in design or in material. It is shown in the diagram, by the stream which goes from the engine towards the condenser, that by far the greatest loss occurs in the engine; and this circumstance, coupled with the fact that the design and manufacture of steam engines form a distinct and almost separate branch of engineering, give ample ground for isolating the engine and considering it apart from other portions of the steam plant.

For this reason the report does not deal with the steam plant as a whole, but only with the steam engine proper, which is defined in the report as consisting of "everything included between the boiler side of the engine stop valve and the exhaust flange."

Much diversity of opinion has existed as to the method of

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stating the thermal economical value of an engine and the standard with which it should be compared. The work of the committee has been directed to these points.

The upper diagram in the plate represents, in the main, the trial of the Louisville Leavitt Pumping Engine as described in the "Transactions of the American Society of Mechanical Engineers," Vol. XVI, and the data are sufficiently full to enable the flow of heat to be stated at all points with fair accuracy. The numerals represent British thermal units flowing per minute; the streams are drawn to such a scale that each inch of width represents a flow of 100,000 B.T.U. per minute. Temperatures are also given.

Starting at the fire grate, it is shown that 183,600 B.T.U. are produced per minute by the combustion of the coal, and that 131,700 of these go direct into the water of the boiler, 10,000 are lost by boiler radiation and leakage, and the remainder, viz: 41,900, pass away with the flue gases. On the way to the economizer, 1,000 B.T.U. are lost by radiation, but in the economizer itself 15,750 B.T.U. are diverted into the feed water, 5,000 B.T.U. are dissipated by radiation, and finally 20,150 B.T.U. pass out of the economizer and into the chimney, and are lost to the steam plant. The heat entering the economizer with the feed water is 5,450 B.T.U., which is added to the 15,750 B.T.U. diverted from the flue gases, thus giving a flow of 21,200 B.T.U. in the feed out of the economizer. Radiation, however, reduces this flow to 20,950 B.T.U. per minute at the entry to the boiler, where a further addition is made of 6,600 B.T.U. returned by the jacket water.

The steam produced by the boiler is thus seen to derive its heat from three streams, as shown on the diagram; the steam finally leaves the boiler with 159,250 B.T.U. per minute. Before this heat gets to the engine, however, 3,100 B.T.U. are lost by radiation and leakage from the steam pipes, so that the flow of heat is reduced to 156,150 B.T.U. per minute, which is the gross supply of heat to the engine; the net supply is less, because there are certain returns of heat to the boiler to be deducted. In the first place, credit has to be given to the engine for the heat which could be imparted by means of the exhaust steam to the feed

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water, inasmuch as the exhaust is theoretically, and very nearly practically, capable of raising the temperature of the feed to the exhaust temperature. On this basis, 7,400 B.T.U. should be credited to the engine, although the actual return to the boiler, or rather to the economizer, is only 5,450 B.T.U. The difference is due to excess of circulating water, which lowers the hot-well temperature, and also to radiation in the feed arrangements, which are a necessary portion of the steam plant, independent of the engine proper, and which are not applied to correct any fault of the engine. The loss of 1,950 B.T.U. should, therefore, be debited to the feed and condensing arrangements, and not to the engine. It will be seen that the 7,400 B.T.U. credited to the engine is equal to the water heat of the feed at the temperature of the exhaust, which is in agreement with the rule given at page 956 for calculating the "heat supplied to the engine," and also with the third recommendation of the committee. In the present case a special credit has to be given to the engine, because 6,750 B.T.U. leave the engine in the jacket water to return to the boiler; but 150 are lost by radiation on the way, so that the net return is 6,600 B.T.U. Only the net return to the boiler should be credited to the engine, because the jackets are applied to correct a fault of the engine, namely, cylinder condensation; hence, any loss to the steam plant that may be entailed by the use of jackets (*i. e.*, the radiation in question) should be reckoned as a loss due to the engine, although it takes place outside the engine. In the case under consideration the jacket water was returned direct to the boiler, but if, as is frequently the case, the jacket water is drained into the hot well, the heat in it can not be credited to the engine, for the reasons given above.

The net supply to the engine can, therefore, be obtained as follows:

	B.T.U.	B.T.U.
Gross supply	...	156,150
Less returnable by feed	7,400	
Less returned by jackets	6,600	
		14,000
Net supply per minute		142,150

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On referring to the plate it will be seen that only 27,260 B.T.U. are utilized as work upon the pistons. The ratio of the heat so utilized to the net heat supplied is called in the report the "thermal efficiency of the engine," and it is to be observed that this is the usual meaning applied to this term, although some writers, notably Mr. Willans, applied the term to another ratio, as mentioned on page 955. In the numerical case under consideration the thermal efficiency is $\frac{27,260}{142,150} = 0.19$.

The engine under discussion indicates 643 H.P.; the heat supplied "per minute per I.H.P." is, therefore, $\frac{142,150}{643} = 221$ B.T.U., and it is this figure which, as recommended in the report, should be used to express the thermal economical value of a steam engine. This recommendation is made with a view of replacing the present usual method of stating the performance in pounds of feed water per I.H.P. per hour, although the latter statement is useful for other purposes.

It will be seen that 1,870 B.T.U. are deducted from the 27,260 utilized as work on the pistons, as engine friction, so that the effective or brake power of the engine corresponds to 25,390 B.T.U. per minute; in other words, the brake H.P. of the engine is 599 —so that the "B.T.U. per minute per B.H.P." are $\frac{142,150}{599} = 237$ —another figure which the committee recommends should be quoted whenever it is possible to ascertain the brake efficiency.

Let it now be supposed that the actual steam engine is replaced by an ideal steam engine, forming part of an idealized steam plant working according to the "Rankine cycle," using for this cycle the name recommended by the committee. It must be assumed that the I.H.P. of the "ideal" engine is the same as that of the "actual" engine, namely, 643 H.P., and that the admission and exhaust temperature are the same, namely, 359 degrees Fahrenheit and 100 degrees Fahrenheit respectively. The flow of heat in the ideal steam plant is represented by the lower diagram in the plate, and it will be observed that all the losses have disappeared, except the flue loss and the heat carried away

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by the condensing water. There are no jackets, but there is an economizer, because, although the boiler is perfect, 31,400 B.T.U. are sent into the flue, since the gases can not be cooled down below the temperature of the water in the boiler, and a portion of this heat can be saved by heating the feed to the steam temperature. The heat returnable by the feed is, of course, less than in the case of the actual engine, owing to the reduced weight of steam passing through the engine. The heat supplied to the ideal engine is, therefore:

	B.T.U.
Gross supply	100,900
Less returned by feed	5,600
Net heat supplied per minute	95,300

The I.H.P. of the ideal steam engine being the same as that of the actual engine, the same number of B.T.U. per minute are utilized as work upon the pistons, namely, 27,260. The thermal efficiency of this ideal steam engine is, therefore, $\frac{27,260}{95,300} = 0.285$, and the B.T.U. per minute per I.H.P. are $\frac{95,300}{643} = 148$, as against 221 for the actual engine. The actual engine, therefore, requires 73 B.T.U. per minute per I.H.P. more than the ideal engine; these heat units are lost on account of imperfections in the actual engine, and can be looked upon as a measure of these imperfections. The ideal steam engine thus becomes the "standard of comparison," as recommended and defined by the committee.

The number of B.T.U. per minute per I.H.P. required by the ideal engine depends on the temperature of the steam at admission and its temperature at exhaust, and also on whether the steam is saturated or superheated. Figs 3 and 3*a* in the report have been drawn to enable this number of B.T.U.'s or of calories to be read off directly in all cases likely to occur in practice.

If the number of B.T.U. per minute per I.H.P. required by the ideal engine be divided by the number needed by the actual engine, there is obtained what has been called the "efficiency ratio" by the committee. In the numerical case under consideration this ratio is $\frac{148}{221} = 0.67$.

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In order to connect this term with recent writings on the steam engine, it should be stated that Mr. Willans called this ratio the "thermal efficiency;" he, however, employed exactly the same standard of comparison as that now recommended by the committee. Professor Osborne Reynolds has called this ratio "the percentage of theoretical efficiency," but his standard of comparison was different. Captain Sankey has called this ratio the "standard thermal efficiency," and has also suggested a somewhat different standard of comparison.

In conclusion, the result of the committee's work can shortly be said to consist in the recommendation that the thermal economical value of steam engines should be stated in B.T.U. per I.H.P. per minute; in defining the standard engine of comparison; and in giving precise directions for the observations to be taken, and for the calculations to be made, in regard to the foregoing.

Report of the Committee.

On the 12th April, 1897, your committee submitted a preliminary report which embodied the gist of the conclusions they had arrived at. * * *

Your committee have now the honor to forward their final report.

There are two methods of stating the thermal economical value of a steam engine.* In the first, which is principally used for scientific purposes, it is expressed as a ratio, and it is in this connection that a so-called "standard" of thermal efficiency is needed; in the second and more ordinary method, an absolute statement is used, such as pounds of feed water per I.H.P., or heating units supplied per I.H.P. per unit of time.

THERMAL ECONOMICAL VALUE EXPRESSED AS A RATIO.

There are several such ratios relating to quite distinct orders of ideas, and the term "thermal efficiency" has been indiscrimi-

* For the purposes of this inquiry a steam engine will be taken to include everything between the boiler side of the engine stop valve and the exhaust flange, so that neither the boiler, the feed arrangements, nor the condenser, if there be one, are taken into consideration.

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nately used for all of them. For instance, the term has been applied by some authors to the ratio which the work done upon the pistons of the engine, and shown by the indicator, bears to the heat supplied to the engine; by others to the ratio of the performance of the engine, as above defined, to that of some ideal engine; and by others even to some quantity not a ratio at all, although more or less representing an economical result.

With the view of avoiding risk of misunderstanding in future, and of obtaining the great advantage which would result from the adoption of a uniform system of nomenclature, your committee submit and recommend for use the following definitions:

The expression, "thermal efficiency," as applied to any heat engine, should mean the ratio between the heat utilized by that engine and the heat supplied to it, or

$$\text{thermal efficiency} = \frac{\text{heat utilized as work on the pistons}}{\text{heat supplied to the engine}}.$$

In the case of any particular actual steam engine this ratio can be determined by calculations based on actual experiment in the following manner:

The heat units utilized as work are to be obtained by measuring the indicator diagrams of the engine in the usual way to ascertain the mechanical work done.

The heat supplied to the engine is to be calculated as the heat required to produce at constant pressure the steam that enters the engine, from water at the temperature of the engine exhaust.* This rule applies whether the steam be saturated or superheated; also whether the engine be non-condensing or condensing.†

In the case of an ideal engine working between certain tem-

* The above is equivalent to the following statement: The heat supplied to the engine per minute is equal to the total heat of the steam entering the engine less the water heat at the temperature of the engine exhaust of the same weight of water. The temperature of the engine exhaust is taken because, theoretically, the feed can be raised by the exhaust to this temperature, although the result is not usually realized in practice.

† Special cases occur when steam is abstracted from the engine before final exhaust to heat the feed or when the steam is "reheated" in the receivers. Subtraction or additions to the heat units supplied must then be made.

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peratures according to some theoretical cycle, the term "thermal efficiency" will equally represent the ratio of heat utilized to heat supplied.

For many important purposes it is required to know both the thermal efficiency of a particular engine and the calculate thermal efficiency of some ideal engine more or less closely corresponding to it. The ratio between these two efficiencies is a matter of special importance. This ratio between two efficiencies has often been itself called an efficiency, but your committee think that this use of the word has led to no little confusion, and consider it undesirable.

The ideal steam engines thus contemplated are the "standards of thermal efficiency" which form the subject of the reference to your committee; but, as in the opinion of your committee the use of the words "thermal efficiency" is undesirable in this connection, they recommend that such an ideal steam engine be called the "standard steam engine of comparison," and that the ratio of the thermal efficiency of any actual steam engine to the corresponding standard steam engine of comparison be called the "efficiency ratio."

It will be seen from the foregoing that two ratios are required to fully express the thermal economical value of a steam engine, namely, the thermal efficiency, which gives the proportion of the heat utilized as work upon the pistons to the heat supplied, and the efficiency ratio, which is the measure of the extent to which the actual engine fails to reach the physical possibilities of the conditions under which it is working.

The next step is to decide what the standard steam engine of comparison should be.

STANDARD STEAM ENGINE OF COMPARISON.

As is well known, a heat engine working on the Carnot cycle would give the maximum utilization of the heat supply; but it is impossible for a steam engine to work on this cycle when the working substance is saturated steam, unless it be provided with a dynamical feed heater, an arrangement probably outside any future developement of the steam engine. For an engine using

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superheated steam produced at constant pressure, the Carnot cycle is thoretically impossible, even with a dynamical feed-heater.

An ideal steam engine working on the cycle defined by Rankine, Clausius and others * gives the maximum utilization of the heat supply when the working substance is steam, either saturated or superheated, when produced at constant pressure, and is to be regarded as the perfect steam engine. In this connection it is to be observed that every working substance has its own cycle of maximum utilization of the heat supply, depending on the method in which heat is applied to it.

Actual steam engines fall far short of the perfect steam engine, owing principally to incomplete expansion, to the use of conducting materials for cylinders, and to the clearances that have to be observed for mechanical and other reasons. Ideal cycles can be devised to take account of these practical necessities for each particular type of engine, but if such a cycle were devised for general use, arbitrary limitations would be required, which your committee do not see their way to recommend.

For saturated steam, within the temperature limits at present in use, the difference between the thermal efficiency of the Carnot cycle and of the Rankine cycle is inconsiderable. For instance, if the higher temperature limit is 370 degrees Fahrenheit and the lower temperature limit is 110 degrees Fahrenheit, the thermal efficiency of the Carnot cycle is 0.313 and the thermal efficiency of the Rankine cycle is 0.283. If the lower limit of temperature be increased to 212 degrees Fahrenheit (in a non-condensing engine) the thermal efficiency of the two cycles is still closer, viz: 0.19 and 0.178. In view of the fact that the efficiency ratio rarely reaches 0.7 in the case of a condensing engine, or 0.8 with a non-condensing engine, there would seem to be little practical objection to using the Carnot cycle instead of the Rankine, while there would be advantage in the former in simplicity of calculation.

* This ideal steam engine has often been called the Clausius engine, but Rankine was the first to describe its cycle. Your committee therefore prefer to call this cycle the Rankine cycle, and it is defined on page 959.

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For superheated steam, however, there is a much greater difference between the thermal efficiencies of the two cycles. For instance, if the pressure is 185 pounds per square inch absolute, and the admission temperature of the steam 650 degrees Fahrenheit, and the lower limit of temperature is 100 degrees Fahrenheit, it will be found that the thermal efficiency of the Carnot cycle 0.495, while the thermal efficiency of the Rankine cycle is only 0.31. Comparison with the Carnot engine might in this case give rise to undue expectations as to the possibilities of superheated steam.*

After careful consideration, your committee recommend an ideal steam engine working as part of the Rankine cycle as the standard steam engine of comparison, both for saturated and for superheated steam engines.

The definition of the Rankine cycle is as follows: It is assumed that all the component parts of the steam plant are perfect, and that there are no losses due to initial condensation, leakage, radiation or conduction, and that there is no clearance in the cylinder. The feed water required is taken into the boiler at the exhaust temperature, and its temperature is gradually raised until that corresponding to saturated steam is reached. Steam is then formed at constant pressure until dry saturated steam is produced, after which, if the steam is to be superheated, heat is added at constant pressure and at increasing temperature, until the required temperature of superheat is reached. The steam is intro-

* The following numerical example also throws some light on this point. Suppose that an engine working with superheated steam of 120 pounds per square inch absolute pressure and 300 degrees Fahrenheit superheat at admission is stated to require 7.6 pounds of feed water per I.H.P. per hour. The temperature of the exhaust is 120 degrees Fahrenheit. Can the statement be true? On calculation it is found that the thermal efficiency of the engine is $\frac{42.4 \times 60}{1,242 \times 7.6} = 0.27$. The thermal efficiency of the Carnot cycle for the limiting temperatures of 641 degrees Fahrenheit and 120 degrees Fahrenheit is 0.473, so that the actual engine only performs 57 per cent. of what the corresponding Carnot cycle engine could do. But the thermal efficiency of the Rankine cycle for this superheated steam is 0.268, so that the actual engine is claimed to do over 100 per cent. of what the Rankine cycle engine could do, or, in other words, does more than is physically possible. Clearly the Carnot cycle helps little in discovering a misstatement of this kind, whilst the Rankine cycle exposes it at once.

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duced into the cylinder at constant pressure, displacing the piston, and performing external work equal to the absolute pressure multiplied by the volume swept through by the piston up to the point of cut-off. Beyond that point expansion takes place adiabatically, doing work until the pressure in the cylinder is equal to the back pressure against which the engine is working. The steam is then completely exhausted from the cylinder at constant pressure corresponding with the lower limit of temperature, work being done on the steam by the engine during exhaust, equal to the absolute back pressure multiplied by the total volume swept through by the piston. The steam is thus removed from the cylinder and the cycle is complete.

To calculate the heat supply in any particular case, the only data required are the higher and lower limits of temperature, and for superheated steam the admission pressure as well.

Higher Limit of Temperature (t_a) *and of Pressure.*—In the ideal Rankine cycle engine just described, the temperature and pressure are the same in the cylinder at cut-off as in the boiler or superheater; but in an actual engine, the temperature and pressure are always less in the cylinder than in the boiler. There are five different places at which the measurements can be taken:

(1) The boiler.
(2) The stop valve.
(3) The valve chest.
(4) The cylinder during admission.
(5) The point of cut-off.

The temperature and pressure of steam in the boiler, owing to the losses in the connecting steam pipes, are of necessity higher than at the stop valve of the engine, and it would be unfair to the engine to reckon these losses against it. Moreover, cases may arise where the steam is superheated in a separately-fired superheater close to the engine. It is, therefore, undesirable to measure the upper limit of temperature and pressure at the boiler.

On the other hand, to take the temperature and pressure in the cylinder during admission, and still more to take them at the point of cut-off, would favor the engine by ignoring some of its defects.

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Taking the temperature and pressure at the valve chest also favors the engine. In many cases there are considerable variations of pressure in the valve chest during the stroke, as was shown by experiments undertaken for the purpose and described in Appendix II.

Your committee, therefore, recommend that the upper limit of pressure and temperature be taken close to, but on the boiler side of, the stop valve.

Lower Limit of Temperature (T_0).—It has been less easy to come to a conclusion as to the lower limit of temperature, many views having been expressed on this subject, for the most part tending to fix the limit, either in accordance with the conditions affecting the exhaust of the actual engine, or at some constant but arbitrary value.

Experiments were made to ascertain the degree of accuracy with which the temperature of the steam in the exhaust of an engine could be measured. These are described in Appendix IV, and the conclusion drawn from them is that this temperature can be obtained with sufficient accuracy, either directly by a thermometer placed in the exhaust pipe, or indirectly by observing the pressure in the exhaust pipe and taking the corresponding steam temperature, provided a vacuum gage of the mercurial barometric type, or an indicator, be used to measure this pressure.

After a considerable amount of discussion, your committee decided to recommend that the lower limit of temperature should be measured in the exhaust pipe outside, but close to, the engine.

This recommendation covers the special cases of an engine working against a high back pressure, and of an engine working, at a considerable terrestrial elevation, in an atmosphere of low barometric pressure.

THERMAL ECONOMICAL VALUE EXPRESSED IN HEAT UNITS.

Referring to page 955, the thermal economy expressed in heat units has now to be considered. It has been frequently pointed out, even as far back as 1881 by Mr. Mair-Rumley, that the usual method of expressing the thermal economy of a steam engine in

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pounds of feed water per hour is inaccurate, because the number of heat units required to produce a pound of steam depends upon the circumstances of its production. The error is unimportant so long as we are dealing with saturated steam, but when using superheated steam the error may be as much as 10 per cent. or even 15 per cent., and cannot therefore be neglected.

If the heat supplied to an engine per minute, as calculated by the rule given on page 956, is divided by the I.H.P., we obtain a number which is a true measure of the thermal economy of the engine, namely, the number of British thermal heat units supplied per minute per I.H.P., and a similar number can be obtained per B.H.P. Further, the B.T.U. required per I.H.P. by the standard steam engine of comparison can also be calculated, if the limiting conditions are given.

The complete statement can be tabulated as follows, two numerical examples being added by way of illustration :—

DATA.

	Numerical examples.	
(1) Stop-valve pressure (absolute) pounds per square inch.....	158	185
(2) Stop-valve temperature, degrees Fahrenheit.....	362	650
(3) Exhaust temperature, degrees Fahrenheit.....	213	100
(4) I.H.P.....	500	1,300
(5) B.H.P.....	450	1,155
(6) Weight of steam entering engine per minute, pounds.....	171	222

RESULTS.

Actual engine:		
(7) B.T.U. supplied per minute per I.H.P.....	345	215
(8) B.T.U. supplied per minute per B.H.P.....	385	242
Standard engine of comparison:		
(9) B.T.U. theoretically required per minute per I.H.P.....	250	136
(10) Efficiency ratio.....	0.725	0.633

The "B.T.U. supplied per minute per I.H.P.," together with the "B.T.U. supplied per minute per B.H.P.," give all the information as regards economy needed by the user, and correspond with the "feed water per I.H.P." and "per B.H.P." at present in use. The addition of the B.T.U. per minute required by the standard engine of comparison gives the further information needed for scientific purposes.

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It will be seen that the number of B.T.U. lost by imperfections in the actual engine can be obtained by the subtraction of line 9 from line 7, which is a valuable and suggestive piece of information.

The estimation of the B.T.U. supplied per I.H.P. from the usual observations made at trials is easy. For instance, suppose the following observations are made with an engine using saturated steam:—

I.H.P.	520
Weight of steam entering engine per minute, pounds	108.3
Stop-valve pressure, pounds per square inch, absolute	170
Exhaust pressure, pounds per square inch, absolute	2

The heat supplied per pound of feed, as defined on page 956, is $1{,}194 - 94 = 1{,}100$ B.T.U. Hence the B.T.U. per minute per I.H.P. $= \frac{108.3 \times 1{,}100}{520} = 229$.

The B.T.U. per H.P. for the standard engine of comparison can be calculated as follows:—

The formula* for the thermal efficiency of the Rankine cycle for saturated steam is

$$\frac{\left(T_a - T_e\right)\left(1 + \frac{L_a}{T_a}\right) - T_e \text{ hyp log } \frac{T_a}{T_e}}{L_a + T_a - T_e},$$

in which formula the increase in the specific heat of water at higher temperatures affects the numerator and denominator nearly equally.

The B.T.U. per minute per H.P. for the standard engine of comparison is 42.4 divided by the thermal efficiency of the Rankine cycle thus:—

For saturated steam, the B.T.U. per minute per H.P. for the standard engine of comparison is:—

* Meaning of the letters used in the following formulas:—

T_a absolute temperature of saturated steam at stop-valve pressure.

T_{a_s} absolute temperature of superheated steam at stop-valve.

T_e absolute temperature in exhaust.

L_a latent heat of steam at temperature T_a.

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$$\frac{42.4\,(L_a + T_a - T_e)}{(T_a - T_e)\left(1 + \frac{L_a}{T_a}\right) - T_e \text{ hyp log } \frac{T_a}{T_e}},$$

and similarly for superheated steam it is:—

$$\frac{42.4\,\{L_a + T_a - T_e + 0.48\,(T_{as} - T_a)\}}{(T_a - T_e)\left(1 + \frac{L_a}{T_a}\right) + 0.48\,(T_{as} - T_a) - T_e\left(\text{hyp log } \frac{T_a}{T_e} + 0.48 \text{ hyp log } \frac{T_{as}}{T_a}\right)}.$$

It will be noticed that the usually accepted figure of 0.48 for the specific heat of superheated steam at constant pressure has been taken, although this figure is open to much doubt.

These formulas being somewhat complex, the curves shown in Fig. 3 have been prepared, from which the B.T.U. per minute per H.P. in the case of saturated steam can be read off directly.*

In the case of superheated steam, the figure is obtained by applying a correction to that got for saturated steam. At the bottom of Fig. 3 is a set of curves marked "coefficient for superheat correction." Against the temperature of saturation corresponding to the stop-valve pressure, and on the curve corresponding to the temperature of the superheated steam (T_{as}), is found a coefficient. This coefficient multiplied by the exhaust temperature, and by the B.T.U. already found, gives the deduction to be made from these B.T.U.†

Further numerical examples are given in Appendix III.

It is further to be observed that this method of statement is applicable to all heat engines whether using steam, gas, oil or air. Calculations in respect of fuel consumption are more readily made than when the feed per I.H.P. is given, as will be seen on referring to Appendix V.

RELATION BETWEEN THERMAL ECONOMY EXPRESSED IN HEAT UNITS AND AS A RATIO.

The thermal efficiency, as defined on page 956, is proportional to the inverse of the B.T.U. required per minute per I.H.P., and

* Thus for $T_a = 350$ degrees and $T_e = 212$ degrees, the figure is 265.

† Thus, let $T_{as} = 500$ degrees, $P_a = 135$ pounds (so that $T_a = 350$ degrees), and $T_e = 212$ degrees. Against 350 degrees, and on the curve for 500 degrees, we read the coefficient 0.00015. This gives the correction thus: $0.00015 \times 212 \times 265 = 8.5$, and $265 - 8.5 = 256.5$, the number of B.T.U.'s required.

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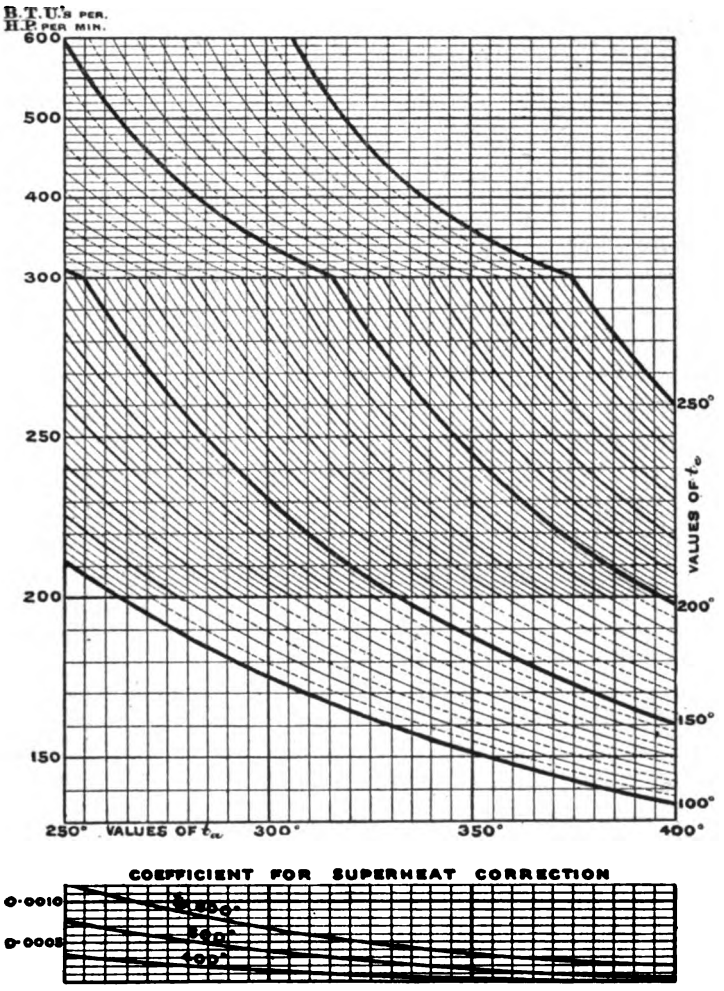

Temperatures are expressed in degrees Fahrenheit.

FIG. 3.

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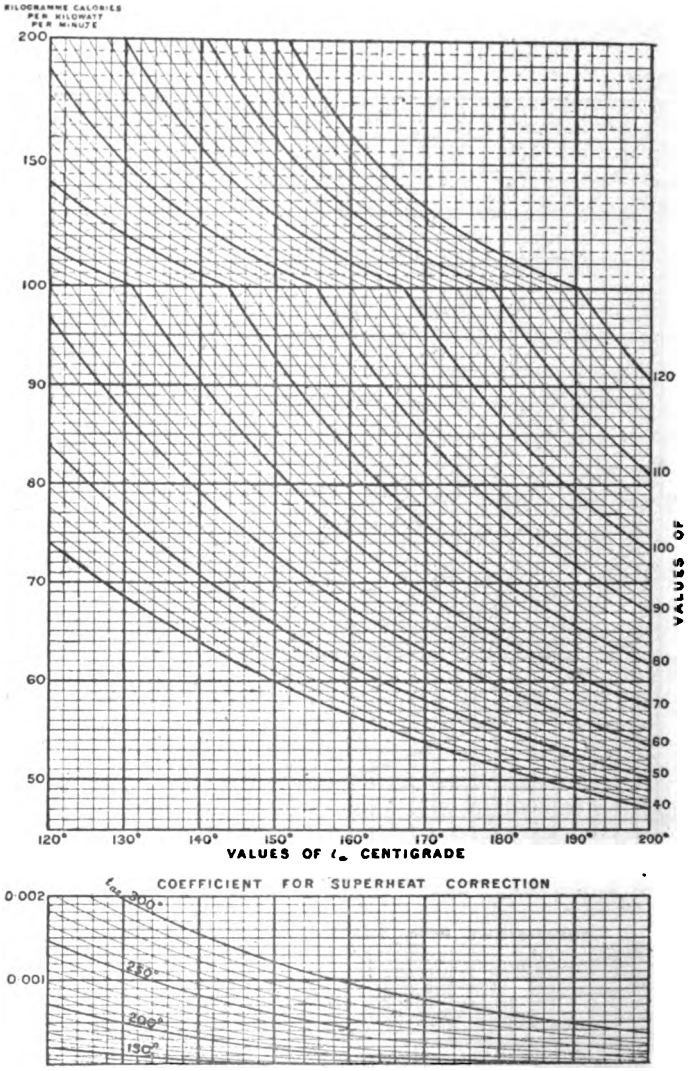

Temperatures are expressed in degrees Centigrade.

FIG. 3*a*.

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if we divide the energy of 1 H.P. per minute expressed in thermal units, namely 42.4, by the B.T.U. required per I.H.P. per minute, we obtain the thermal efficiency.*

The efficiency ratio, as defined on page 956, is equal to the B.T.U. theoretically required per I.H.P. per minute by the standard engine of comparison divided by the B.T.U. supplied per minute per I.H.P. to the actual engine.†

RECOMMENDATIONS BY THE COMMITTEE.

Having considered the various questions connected with the subject as detailed in the report, your committee recommend:

1. That "thermal efficiency" as applied to any heat engine should mean the ratio between the heat utilized as work on the piston by that engine and the heat supplied to it.

2. That the heat utilized be obtained by measuring the indicator diagrams in the usual way.

3. That in the case of a steam engine, the heat supplied be calculated as the total heat of the steam entering the engine less the water heat of the same weight of water at the temperature of the engine exhaust, both quantities being reckoned from 32 degrees Fahrenheit.

4. That the temperature and pressure limits, both for saturated and superheated steam, be as follows:

Upper limit: the temperature and pressure close to, but on the boiler side of, the engine stop valve, except for the purpose of calculating the standard of comparison in cases when the stop valve is purposely used for reducing the pressure. In such cases the temperature of the steam at the reduced pressure shall be substituted. In the case of saturated steam the temperature corresponding to the pressure can be taken.

Lower limit: the temperature in the exhaust pipe close to, but outside, the engine. The temperature corresponding to the pressure of the exhaust steam can be taken.

---

*Thus in the first numerical example, page 962, the thermal efficiency is $\frac{42.4}{345}=0.123$.

† In the numerical example for saturated steam, page 291, this efficiency ratio is $\frac{250}{345}=0.725$, and in the example for superheated steam it is $\frac{136}{215}=0.633$.

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5. That a standard steam engine of comparison be adopted, and that it be the ideal steam engine working on the Rankine cycle between the same temperature and pressure limits as the actual engine to be compared.

6. That the ratio between the thermal efficiency of an actual engine and the thermal efficiency of the corresponding standard steam engine of comparison be called the efficiency ratio.

7. That it is desirable to state the thermal economy of a steam engine in terms of the thermal units required per minute per I.H.P., and that, when possible, the thermal units required per minute per B.H.P. be also stated.

8. That, for scientific purposes, there be also stated the thermal units required per minute per H.P. by the standard engine of comparison, which can readily be obtained from a diagram similar to that given in Fig. 3, and from which the efficiency ratio can be deduced.

Your committee would also suggest that in papers submitted to the Institution bearing on steam-engine economy, authors be invited to conform to the above recommendations.

Appendix III.

FOURTEEN EXAMPLES OF STEAM ENGINES WORKING UNDER VARYING CONDITIONS.

Referring to page 290, the accompanying Table gives an abstract of the working out of some examples of steam engines working under various conditions. The following points are worth noticing:

Examples 1 and 2.—Comparing examples 1 and 2, it will be seen that according to column IV both these engines are doing about 56 per cent. of the theoretical possibility, due to their environment, that is, they both have an efficiency ratio of 0.56. The thermal efficiency of the first example is only 0.12, and in the second it is as much as 0.17. The improvement in work return is due to the higher boiler pressure and better vacuum. If, however, these two examples are compared by the figures given in column 1 it would appear that the *Iona's* engine is

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making better use of its opportunities in the proportion of 58 to 41. The former comparison, viz: 56, is surely the more accurate; but it must not be argued from this that if the *Ville de Douvres* engines were put to work with 167 pounds stop-valve pressure and 0.7 pound per square inch exhaust pressure, that they would still have an efficiency ratio of 0.56. It will, of course, be a less ratio, inasmuch, as the engines would not then be suitably designed for the new conditions.

Examples 4 and 7.—These examples show that the engine was in each case arranged so as to make the same use of its opportunities, namely, 0.74 and 0.73 efficiency ratio, which is reasonable, seeing that the cut-off had been adjusted by Mr. Willans in each case to give the best results. The thermal efficiency in the first case is, however, greater, owing to the better conditions under which the engine of example 4 is working.

Examples 2 and 6.—The thermal efficiency is greater in example 6 than in example 2, because the engine makes better use of its opportunities, which are not quite so good in example 6 as they are in example 2, owing to the exhaust being at a higher pressure. This example 6, together with example 2, illustrates also the disadvantage of taking the temperature of injection as the lower temperature. If this temperature had been chosen, the efficiency ratio for example 2 would have been 0.51, and 0.50 for example 6, which would have made it appear that engine 6 is not quite so good as engine 2, whereas in reality it is better.

Examples 7, 8 and 9 have very nearly the same thermal efficiency, notwithstanding the varying conditions as regards back pressure; the efficiency ratio gives the reason. This particular engine had been designed to give the best results when non-condensing, and its efficiency ratio under these circumstances is 0.73 (columns III and IV). It was then put on the condenser without any change, not even of cut-off, and being then unsuited to its environment gave only 0.66 with a bad vacuum, and only 0.51 with a moderate vacuum. If, in this latter case, without changing the design of the engine in any way, but merely altering the

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Data abstracted from table issued to the members of the committee on the 23d December, 1896.							Thermal efficiency.	Efficiency ratios.				Proposed method of comparison in B.T.U.		
								Fixed lower limit of temperature.*		Lower limit of temperature varying with conditions of running.*				
A.	B.	C.	F.	J.	K.	N.		I.	II.	III.	IV.			
Case.	Engine.	Reference and authority.	Temperature of steam at stop valve.	Temperature of steam in exhaust pipe just outside engine.	Temperature in hot well.	Pounds of feed water per I.H.P. per hour.		Non-condensing, 212° F. Condensing, 100° F.	All steam engines 100° F.	Hot-well temperature (col. K).	Temperature in exhaust just outside engine (col. J).	B.T.U. per I.H.P. per minute.	B.T.U. per B.H.P. per minute.	B.T.U. per H.P. per minute for standard engine of comparison.
			° F.	° F.	° F.									
1	S. S. *Ville de Douvres*	Dr. Kennedy, Proc. Inst. Mech. E.; Prof. Hudson Beare's Report	(338)	160	160	20.8	0.12	0.41	0.41	0.56	0.56	367	...	205
2	S. S. *Iona*	do.	(367)	91	75	13.4	0.17	0.58	0.58	0.52	0.56	254	...	141
3	Willans (experimental engine)	Willans non-condensing trials; Min. Proc. Inst. C. E., vol. xciii $C\frac{80}{3.2}$	(322)	213	...	26.2	0.10	0.72	0.34	...	0.74	436	506	321
4		$C\frac{160}{6}$	(370)	212	...	19.2	0.13	0.73	0.40	...	0.74	325	356	239
5	do.	Willans, condensing trials; Excerpt Min. Proc. Inst. C. E., vol. cxiv $\frac{T75}{20.6}$	(312)	91	(70)	15.3	0.15	0.60	0.60	0.51	0.57	285	458	162
6		$\frac{T175}{12.36}$	(375)	105	(70)	12.7	0.18	0.60	0.60	0.53	0.61	238	268	145
7	Willans II-S engine, driving "Holmes" dynamo	Dr. Kennedy, tests made at Thames Ditton on the 20th May, 1893	(362)	213	...	20.5	0.12	0.72	0.38	...	0.73	345	383	250
8			(362)	193	(190)	(19.6)	0.13	0.40	0.40	0.65	0.66	337	374	220
9			(362)	135	(130)	18.2	0.13	0.43	0.43	0.50	0.51	330	367	168
10	"Milwaukee" pumping engine	Thurston, Trans. Am. Soc. Mech. Eng., vol. xv	350	126	105	11.7	0.20	0.69	0.69	0.71	0.79	213	235	168
11	do. H.P.C.	do.	350	277	...	38.4	0.07	(0.41)	(0.21)	...	0.80	603	...	481
12	do. I.P.C.	do.	277	216	...	39.7	0.06	(0.76)	(0.26)	...	0.81	649	...	527
13	do. L.P.C.	do.	216	126	105	29.3	0.08	(0.62)	(0.62)	0.52	0.64	515	...	328
14	Imaginary steam engine	.....	338	162	160	13.0	0.19	0.64	0.64	0.90	0.91	228	...	208

* In all cases the stop-valve temperature was chosen as the higher limit of temperature. Various values were chosen for the lower limit of temperature.

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proportion of the cylinders and the cut-off, the efficiency ratio when condensing would have risen to about 0.65.

Example 8.—In this example, if treated as a condensing engine with 100 degrees Fahrenheit for the lower limit of the standard engine of comparison, the efficiency ratio (column I or II) comes out at only 0.40; but when the vacuum improves, and the engine is still less suited to its environment, example 9, a better efficiency ratio of 0.43 is obtained. This is, obviously, not a helpful comparison.

Example 10 gives the results of one of the best trials on record, and it is interesting to note that even this engine is only able to do 79 per cent. of the possibilities. This may be looked upon as the high-water mark of present engine economy with saturated steam.

Examples 11 and 12 show that the H.P. and the intermediate cylinders of this engine are making rather better use of their opportunities than the L.P. cylinder. A considerable portion of the loss of the L.P. cylinder is of course due to the necessary cutting off of the toe of the diagram in this cylinder.

Example 14.—The efficiency ratio in columns III and IV is given as 0.90 and 0.91. This efficiency ratio is so high that it ought to excite suspicion as to the accuracy of the test. The thermal efficiency is 0.19, which, although high, is not so good as that in example 10. In columns I and II the efficiency ratio (with fixed lower limits of temperature of 100 degrees Fahrenheit) is only 0.64, and this figure would not call attention to there being anything wrong with the test. If the matter is inquired into a little further, however, and the engine is compared with one working on an ideal cycle, having for its lower temperature limit the temperature of the exhaust in the L.P. cylinder, and with the toe cut off at 2 pounds above the exhaust, it will be found that the efficiency ratio is no less than 0.96 or 0.97; that is to say, this engine would be actually doing within 3 per cent. of the real theoretical possibility. In other words, it is practically an impossible engine. One object of the efficiency ratio is to detect error. This it does, as is seen above, if the lower limit of temperature is taken as that in the exhaust, but it fails to do so if a fixed lower limit of temperature of 100 degrees Fahrenheit is

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taken. It is further interesting to note that, according to column I, engine 14 is not so good as engine 10, whereas in reality it is so much better that it is impossible.

Cases will occur in which it is of scientific interest to determine the efficiency ratio of any particular cylinder of a compound or of a triple-expansion engine. This can be readily done if the temperatures are taken as in column IV (see examples 11, 12 and 13), but obviously absurd results are obtained if a fixed lower temperature is taken, as in columns I and II.

Appendix IV.

Experiments were made by Prof. Beare and Capt. Sankey to determine the degree of accuracy with which the lower limit of

TABLE OF LOWER LIMITS OF TEMPERATURE.

Trial.	Speed of engine.	Vacuum. Mean gage readings.		Temperature in degrees Fahrenheit.		
				Corresponding to pressure shown by—		Mean readings of mercurial thermometer.
		Mercurial gage.	Bourdon gage.	Mercurial gage.	Bourdon gage.	
1	455	27.58	27.9	107.8	102.45	105.0
2	455	23.90	23.9	141.6	141.6	143.8
3	455	21.22	21.4	156.05	155.3	158.9 *a*
4 *b*	455	.....	18.5	.....	167.2	170.9
5	455	14.9	15.0	179.5	179.2	181.5
6 *c*	455	11.2	11.0	189.6	190.1	191.7
8	455	8.55	8.0	195.7	196.9	196.1
7	455	11.3	11.0	189.3	189.95	190.7
8	200	7.5	7.2	198.1	198.7	191.5
9	450	8.35	.....	196.2	.....	195.7
10	250	8.5	.....	195.9	.....	188.8 *d*
11	445	27.1	27.5	114.1	108.4	111.5 *e*
12 *f*	150	27.6	28.0	107.5	101.7	116.7
13 *g*	450	27.3	.....	111.5	.....	111.4
14	450	27.2	27.6	112.0 *h*	107.6	110.0
15	450	—0.1″ water press.	.....	211.7	.....	211.8 *h*

a Gages and thermometer varying slightly, but in time with each other.
b Flying readings.
c Flying readings.
d As Engine slowed down the temperature fell and the vacuum increased.
e At slow speed the exhaust took time to cool from previous trial, but cooled quickly on raising speed.
f Speed dropped from 445 to 150. At first the temperature fell to 108 degrees and the vacuum rose to 27.6 inches by the mercurial gage. Afterwards, without any change in the vacuum, the temperature slowly rose to 116.7 degrees.
g Speed raised quickly. Vacuum fell slightly, and temperature also fell to 110 degrees quickly.
h Non-condensing. The temperature rose at once on starting engine.

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temperature could be obtained. The same engine was used for these experiments as for the first set of those described in Appendix II. The pressure in the exhaust pipe was measured by a water U-tube in the case of the non-condensing experiments, and by a mercury vacuum gage when the engine was running condensing. The thermometer used was subsequently calibrated at University College by Prof. Beare.

After trial No. 15, the speed of the engine was gradually reduced—but no change occurred in the readings. The engine was then stopped; there was no change for about one minute, then the thermometer began to fall very slowly.

Appendix V.

NUMERICAL EXAMPLE OF METHOD OF CALCULATING THE FUEL CONSUMPTION WHEN THE B.T.U.'S PER MINUTE PER I.H.P. ARE GIVEN.

It is stated at page 964 that calculations in respect of fuel consumption can be readily made when the thermal economy of a steam engine is expressed in B.T.U. per I.H.P. The following example is given by way of illustration:

A steam engine requires 235 B.T.U. per minute per I.H.P. The coal used has a calorific value of 12,000 B.T.U. per pound, and 70 per cent. of the heat in the coal is transmitted to the steam; or, in other words, 8,400 B.T.U. per pound of coal burnt are transmitted to the steam. Hence the coal required per I.H.P. per hour is $235 \times 60 \div 8{,}400 = 1.68$ pounds. This calculation is, however, based on the supposition that the feed is at the temperature of the exhaust of the engine, since the heat supplied to the engine is calculated from this temperature. The feed temperature may be higher or lower, according to circumstances, and an allowance must be made. This allowance is easily made in the case of saturated steam, because the total heat required per pound of feed does not differ much from 1,000 B.T.U., so that the correction is sensibly one-thousandth of the difference of temperature between the exhaust and the feed multiplied by the coal consumption obtained as above. Thus, supposing the feed in the above numerical example is 100 degrees Fahrenheit above the exhaust temperature (owing, say, to the

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use of an economizer), the coal consumption will be $100 \div 1{,}000 \times 1.68$ less, or $1.68 - 0.17 = 1.51$ pounds per I.H.P. per hour. Or, again, supposing that in the case of a non-condensing engine the coal consumption works out to 2.32 pounds and the feed is at 62 degrees Fahrenheit, owing to there being no economizer or feed heater, the correction will be $\frac{1}{1000}(212-62)$ $2.32 = +0.35$, and the coal consumption becomes 2.67 pounds per I.H.P. per hour.

In the case of superheated steam, the correction becomes

$$\frac{\text{feed temperature} - \text{exhaust temperature}}{1{,}000 + 0.48 \times \text{degrees of superheat}}.$$

Thus, taking the second example on page 962, and supposing that 9,000 B.T.U. per pound of coal burnt are transmitted to the steam, the coal consumption is, if the feed is at exhaust temperature, $215 \times 60 \div 9{,}000 = 1.43$ pounds of coal per I.H.P. per hour. If the feed temperature is, however, 320 degrees Fahrenheit, the correction according to the rule becomes $100 - 320 \div 1{,}000 + 0.48 \times 275 = -0.19$ nearly, and the coal consumption is $1.43 - 0.19 = 1.24$ pounds per I.H.P. per hour.

Appendix VI.

NUMERICAL EXAMPLES OF THE METHOD OF CALCULATING THE B.T.U. PER MINUTE PER I.H.P.

The principal supply of heat from the boiler to a steam engine is effected by means of the steam entering the cylinders, but heat can also be supplied by the intermediary of jackets or reheaters. A portion of the heat thus entering the engine is returnable to the boiler. For instance, the exhaust steam from the cylinders can theoretically heat the feed water to the temperature of the exhaust, and in some cases live steam from a receiver is taken to heat the feed. In the latter case the heat returned to the boiler per minute is clearly the weight of feed water per minute multiplied by the number of degrees through which the feed is raised in temperature.

The heat returned by jackets and reheaters can be calculated if the weight of steam passing through them and the tempera-

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ture at which the resulting water is returned to the boiler are known.

The expression "heat returnable" has been advisedly used, because in practice the heat actually returned to the boiler is generally less, owing to a variety of causes over which the engine has no control. For instance, in the case of a non-condensing engine, a feed heater may not have been fitted, or, if there is one, it may be unable to raise the feed to exhaust temperature. Such losses should not, however, be charged against the engine, but against the feed arrangements.

The following numerical examples show how the various quantities of heat referred to above can be calculated, and the heat supply to the engine obtained.

With one exception, the data have been obtained from the actual published tests referred to in each case. In many instances the published figures do not give the "temperature of the steam at the stop valve," or the "temperature in the exhaust close to the engine," as recommended by the committee. In such cases either the temperature in the boiler or in the condenser have been taken as equivalent for the corresponding temperatures recommended by the committee.

EXAMPLE 1.—NON-CONDENSING NON-JACKETED COMPOUND ENGINE.

Willans Trial C 80 + 3.2 (Minutes of Proceedings Inst. C. E., Vol. xciii).

Data—	
I.H.P.	24.9
Weight of steam entering engine, pounds per minute	10.86
Temperature at stop-valve, degrees Fahrenheit	322
Temperature in exhaust, degrees Fahrenheit	213
Result—	
Total heat of 10.86 pounds of steam passing through the cylinders	12,800
Less heat returnable in feed from exhaust	1,980
Net heat supply per minute	10,820
B.T.U. per I.H.P. per minute (10,820 + 24.9)	435

EXAMPLE 2.—CONDENSING NON-JACKETED COMPOUND ENGINES.

Engine of S. S. *Colchester* (Procedings Inst. Mech. Eng., 1890, No. 2).

Data—	
I.H.P.	1,980
Weight of steam entering engine, pounds per minute	717
Temperature of steam at stop-valve, degrees Fahrenheit	325
in exhaust, degrees Fahrenheit	135

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Result—

Total heat of 717 pounds of steam passing through cylinders	847,000
Less heat returnable in the feed from the exhaust	74,100
Net heat supply per minute	772,900
B.T.U. per minute per I.H.P. (772,900 ÷ 1,980)	391

EXAMPLE 3.—CONDENSING JACKETED COMPOUND ENGINE.

Engines of S. S. *Iona* (Proceedings Inst. Mech. Eng., 1891, No. 3).

Data—

I.H.P.	645
Weight of steam through cylinders, pounds per minute	136.5
H.P. jacket (discharged into feed tanks)	6.2
Temperature at the stop valve, degrees Fahrenheit	373
in the exhaust, degrees Fahrenheit	90

Result—

Total heat of 136.5 pounds of steam passing through cylinders	163,000	
Less heat returnable in the feed from the exhaust	7,920	
		155,080
Total heat of 6.2 pounds of steam passing into H.P. jacket	7,420	
No heat is returned by jacket, water being discharged into feed tanks	0	
		7,420
Net heat supply per minute		162,500
B.T.U. per minute per I.H.P. (162,500 ÷ 645)		252

EXAMPLE 4.—CONDENSING COMPOUND ENGINE WITH JACKETS AND REHEATER.

Louisville Leavitt Engine (Trans. American Soc. M. E., Vol. xvi).

Data—

I.H.P.	643
Weight of steam through cylinders, pounds per minute	109
jackets, pounds per minute	12
reheater, pounds per minute	10
Temperature of steam at engine stop-valve, degrees Fahrenheit	359
in exhaust, degrees Fahrenheit	102
jacket and reheater water at return to boiler, degrees Fahrenheit	328

Results—

Total heat of 109 pounds of steam passing through the cylinder,	129,950	
Less heat returnable in the feed from the exhaust	7,400	
		122,550
Total heat of 12 pounds of steam into jackets	14,300	
Less heat returned (at 328 degrees)	3,600	
		10,700
Total heat of 10 pounds into reheater	11,900	
Less heat returned (at 328 degrees)	3,000	
		8,900
Net heat supply per minute		142,150
B.T.U. per minute per I.H.P. (142,110 ÷ 643)		221

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EXAMPLE 5.—ENGINE IN WHICH STEAM IS ABSTRACTED FROM INTERMEDIATE RECEIVER TO HEAT THE FEED.

Imaginary Case. Condensing, non-jacketed.

Data—		
I.H.P.		1,000
Weight of steam in pounds per minute passing into engine		300
Temperature at engine stop-valve, degrees Fahrenheit		370
in exhaust pipe, degrees Fahrenheit		120
Rise in temperature of feed due to steam taken from receiver, degrees Fahrenheit		100
Result—		
Total heat of 300 pounds passing into engine		359,000
Less heat returnable in the feed from the exhaust	26,400	
Less heat returned from receiver steam by the feed	30,000	
Total heat returned		56,400
Net heat supply per minute		302,600
B.T.U. per minute per I.H.P. (302,600 ÷ 1,000)		302.6

EXAMPLE 6.—SIMPLE NON-CONDENSING ENGINE USING SUPERHEATED STEAM SCHMIDT MOTOR.

No. 6 Trial (Minutes of Proceedings Inst. C. E., vol. cxxviii).

Data—		
I.H.P.		19.85
Weight of steam in pounds per minute passing through the cylinders		5.64
Pressure of steam at engines, pounds per square inch (absolute)		131.6
Temperature of steam at engine, degrees Fahrenheit		674
in exhaust, degrees Fahrenheit		217
Result—		
Total heat of 5.64 pounds of saturated steam passing through cylinder	6,700	
Superheat of 5.64 pounds of steam passing through cylinders	880	
Total heat supplied to engine per minute	7,580	
Less heat returnable in the feed from the exhaust	1,050	
Net heat supply per minute		6,530
B.T.U. per minute per I.H.P. (6,530 ÷ 19.85)		329

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NOTES.

SIMILAR STRUCTURES AND MACHINES.

Professor Archibald Barr, D. Sc., in a paper on the "Comparisons of Similar Structures and Machines," states as follows:

Powers and Weights of Similar Engines.—We have seen that similar cylinders, pistons, etc.—in fact, similar engines—are alike suitable to bear the same statical steam pressure. But the areas of the pistons are as the squares of the dimensions. Hence, the powers for the same piston speed are as the squares of the dimensions. The powers would be as the cubes of the dimensions for the same number of revolutions per minute. The stress in a fly-wheel rim, due to centrifugal action, is proportional to the square of the velocity of the rim, whatever be the diameter of the wheel. Hence, the stresses in similar fly wheels are of like intensities when the wheels revolve at numbers of revolutions per minute inversely as their diameters. A like rule will be seen to apply to all inertia stresses in similar mechanisms. Thus, in two similar engines the cross-sectional areas of the piston rods are as the squares of the dimensions, while the weights of the pistons, etc., are as the cubes. To produce like severity of stress due to inertia, therefore, the accelerations of the masses must be inversely as the dimensions. Now, suppose the engines to run at numbers of revolutions inversely as the dimensions—*i. e.*, at the same piston speed. Then the maximum speeds of the pistons will be the same, but the times taken to get up the speed will be in the ratio of the dimensions. The accelerations will, therefore, be inversely as the dimensions, and then, as we have seen, the severity of the inertia stresses will be the same in both engines. This result, coupled with what we have seen above regarding the steam pressures, leads to the important result that, mechanically, similar engines (neglecting the small statical effects of their weights) are alike suitable to work at the same steam pressure and at the same piston speed—that is, at numbers of

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revolutions per minute inversely as their dimensions. The powers will then be as the squares, whereas the weights will be as the cubes of the linear dimensions.

In other words, the maximum powers of similar engines per ton of weight will vary inversely as the linear dimensions, or inversely as the square roots of the powers. We have, therefore, the important result that we can get a greater horsepower from 100 tons of metal by making it into a number of small steam engines than into one large one. I do not know whether the bearing of this upon the use of twin or triple screws is usually realized, but it is well known that the maximum power per ton of small engines is greater than that of large ones for the same steam pressure and the same piston speed.

In a paper read before the Institution of Civil Engineers, Sir John Durston and Mr. H. J. Oram gave some most interesting details regarding the performances of engines in different types of war vessels. The results are not strictly comparable, since the engines of the large and small vessels are not of the same design, and the steam pressures and piston speeds are somewhat different; still a rough comparison or contrast may be made. The four-cylinder triple-expansion engines of the first-class cruiser *Powerful*, working at a steam pressure of 207 pounds per square inch and a piston speed of 905 feet per minute, developed 25,900 horsepower. This works out to be 11.58 horsepower per ton of machinery. The four-cylinder triple-expansion engines of the torpedo-boat destroyer *Angler*, working at a steam pressure of 210 pounds per square inch, and a piston speed of 1,187.4 feet per minute, developed 5,971.5 horsepower, which works out at about 45.9 horsepower per ton of machinery. These small engines, if working against a resistance that would bring them to the same piston speed as the engines of the great cruiser, would develop about 4,600 horsepower—assuming the distribution of steam to remain the same—or, say, 35.4 horsepower per ton. Comparing the two engines on this basis, we have the ratio of the horsepowers per ton as 1 to 3.05, and the inverse ratio of the square roots of the horsepowers as 1 to 2.37. The agreement is as close as we could expect, considering

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what may be included in calculations which are based on the weight of the "machinery complete," and that the engines are not quite similar in proportions. It will be observed that the power per ton developed by the smaller engines is even greater in comparison with the power of the larger ones than our formula would lead us to expect. This may be partly due to a less economical distribution of the steam, and partly to a smaller margin of safety in the smaller engines, and partly to the fact that the smaller engines are designed for a higher piston speed, which would mean that they will be of lighter construction and of superior materials.

We see also that the same rule would apply to similar boilers, though, of course, large and small boilers are not usually made even approximately similar in design. The grate area and heating surface would increase as the square of the linear dimensions, whereas the weight of boiler and of the contained water would increase as the cube. The bearing of this upon the question of having a large number of small boilers in a ship instead of a small number of large ones, is very important.

Now apply these results, and those above deduced with respect to bodies falling in air, to the flying machine problem. It follows from what has been said above, that the weights of the aëroplanes or other supporting parts of flying machines, would require to increase more rapidly than the cubes of the linear dimensions (assuming that the smaller has the thinnest planes, &c., that will do), and that the power required to support even similar machines in the air would increase in higher ratio than the cubes of the dimensions. But the maximum power of similar boilers and engines would only be as the squares of the dimensions. Hence we see that, as with Nature, it is easy to make a small flying machine, but exceedingly difficult to make a large one. When we hear that someone has made a successful flying machine, we should inquire into its scale. A success with a model by no means indicates a similar success with a full-sized apparatus. Mr. Maxim seems to be the only one who has sufficiently realized this aspect of the problem, and has demonstrated experimentally how a flying machine, of what we may call full size, may be constructed.

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UNSERVICEABLE INVENTIONS.

So long as hope springs eternal in the human breast, so long as man is ambitious to improve his material condition, or so long as inventors, those "who seek to add their part to the progress of human happiness, knowledge and power by improvements on things existing or new departures on untried lines" exist, so long will inventions be produced, be they wise or otherwise. That the object sought is usually of a mercenary character will be conceded; that the results attained are largely financially unfortunate is due to a number of causes not difficult to suggest. It is a sad commentary on the fatuity of the human mind to take note of the overwhelming preponderance of patents that answer no valuable purpose.

A large proportion of alleged inventions are by people utterly unacquainted with the subject, either technically or practically. A sailor would not be expected to satisfactorily plan an agricultural implement, yet he may not be legally restrained from the attempt. The Patent Office asks no questions concerning the inventor's business, knowledge or training, as, indeed, it could not well do. Its only requirements are that the invention must be novel, in the sense of not having been publicly known for more than two years; useful, which it interprets quite differently from the usual accepted meaning, holding it to be synonymous with harmless; and the actual personal product of the petitioner. It claims and attempts no censorship on the practicability, worth, value or usefulness of an invention, and, in this respect, its actions may be considered wise, for the things regarded by many as foolish to-day may be looked upon differently to-morrow. Therefore, no hope can be expected from this quarter in lessening the number of unwise and unprofitable patents; neither can the attorneys, nor middlemen, be expected to turn away the dollars of prospective clients, although it is believed that most solicitors who value their reputation and are sufficiently competent will, if desired, point out, diplomatically perhaps, faults and fallacies, even at a loss to themselves.

Fully 90 per cent. of the total number of patents granted may

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be truly said to be unserviceable inventions. These may be subdivided roughly into three classes:

First, those which are suppressed by being bought up by competitive concerns, who may prefer to make use of some inferior device, possibly, rather than exploit the later invention. This is the case with numerous inventions, especially relating to domestic and automatic machinery, made in large quantities, for which an expensive equipment for manufacturing may be necessary. Examples are to be found in typewriters, telephones, registers and similar mechanisms owned and controlled by large corporations. A knowledge of these inventions is usually sedulously kept from the general public. It may be said that as this class is but little known and has never been in use, the public has lost nothing, because it never had the invention in use. Be it remembered that it is a fundamental consideration that a patent, to be valid, must be new. Again, the inventor usually realizes something, financially, for his labor in these cases.

Second, those inventions which are simply and easily made, those in the nature of personal belongings which anyone can make with little fear from the law in so doing. These, unless in the hands of parties able and prepared by experience and equipment to manufacture and place on the market in large quantities and at low prices, might as well have never been conceived, so far as profits go, by the inventor. Examples of this class are found in mechanical instruments, calipers, gages, etc., the variety of which is almost as large as the number of individuals making them.

Of the third class, to which the great majority belong, are those inventions which are inherently useless from their lack of practicability, either in construction or use. Examples are to be found in every possible field of contrivance. If one successful invention is made it is sure to be followed by a crop of would-be rivals, each certain that his idea is superior. Yesterday it was cycles; to-day it is automobiles; to-morrow something else. There is no doubt but that the calling out of a large number of ideas on one subject is an excellent thing; that many of these ideas should be unserviceable is to be expected.

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It is believed that we might profitably weed out most of these useless patents, and probably force some of the more meritorious into use, by following the practice of the majority of foreign countries, in either obliging the working of a patent within a specified length of time, under penalty of forfeiture, or in imposing a system of annually increasing taxes. The new patent law of Austria does the latter, Germany does both, while Great Britain depends upon taxation to remove her useless inventions.

Another valuable custom which we might beneficially borrow is that of compulsory licenses, whereby if a patentee finds that he cannot work his invention without using a previous patent he may ask for a license to use the same, granting in turn to the owner of the prior patent a license to use his own invention. This should be whenever failure of the patentee to grant licenses can be shown; whenever the patent is not being worked; or the reasonable requirements of the public with respect to the invention can not be supplied. These compulsory licenses may be ordered on such terms as may be just, according to the circumstances of the case, in fifteen foreign countries, including several which have lately revised their patent laws.

It would also seem that some steps should be taken to debar from soliciting such attorneys as persist in offering premiums, prizes and the like, and by blatant advertising seek to allure and entrap the unsophisticated into vain attempts at invention. The advice offered by many, to "Protect Your Ideas," would far more wisely and reasonably read, "Perfect Your Inventions." It is a fallacy that is almost universally believed, that it is the course of wisdom to hurry an invention into the Patent Office. While this course may be wise in a few instances of a special nature, it is unwise with the majority of inventions, as the Government allows two full years of time in which to perfect the same. During this time an inventor may experiment and exploit as much as he likes, prove or disprove his theories, improve and add to his invention all that his experiments may disclose, and may even dispose of his prospective rights, without any disparagement to his patent privileges.

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Should this course be taken, our Patent Office would not be so largely filled with what we have termed Unserviceable Inventions.

[We are in entire sympathy with the policy of taxing patents for the object described and for the benefit of inventors. It is of common occurrence for a successful inventor to find himself at the mercy of the owner of some old, but in itself useless, because impracticable, invention. The first inventor produced nothing of value, except as the second gave it value, and yet the second must pay the first for his own work! The system which keeps thousands of useless patents alive for no other purpose than to embarrass future inventors cannot be successfully defended. We have, however, no faith in the plan of requiring patents to be worked. Many alternative patents are taken out for the same purpose and by the same inventor, the intention being to make the best only, but to prevent others from making something nearly as good. This we regard as legitimate, and, in fact, many cases arise in which the inventor's interests can be protected in no other way. Again, the adoption of improvements often involves discarding devices which, while inferior, yet could not properly or safely be given to competitors, and to require the old devices to be made would discourage the adoption of new ones. Moreover, the requirement is a dead letter, so far as its real objects are concerned. This provision is in force in Canada, and we know of a case in which to meet it the inventor made *one* machine there and then stored it away. The patent had been worked (!) and anyone wanting the machine was at liberty to buy it, and in case of a sale a second one would have been made, so that the manufacture would have been "continuous," as required by law. In point of fact, the existence of a machine was not known to the public, and it was never sold, and certainly the law could hardly require the inventor to make it known by advertising it; and if it did, the advertising could easily be done on the same scale as the manufacture. The requirements of the law had been met, however, and the patent protected, and in his own good time the inventor sold it, and real manufacture under it was begun long after it would have expired if the patent had not been "worked." What is the use of being an inventor if one has not enough in-

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genuity to get around a law like that?—ED.]—W. E. Willis, in the "American Machinist."

SMOKE PREVENTION AND BOILER RATING.

The Proceedings of the Engineers' Society of Western Pennsylvania, just issued, contains the recommendations of the Committee on Smoke Prevention appointed some months ago mainly to furnish a rule for the rating of boilers. The committee has gone quite carefully into the subject, collecting information and data from makers of boilers and automatic stokers, besides consulting with experienced engineers.

In the matter of rating of steaming-producing plants, the following three divisions were discussed: (1) Heating surface per horsepower; (2) grate surface per horsepower, and (3) amount of draft. The committee did not think it wise to recommend any fixed amount of heating surface per horsepower, partly because some boilers are working economically with less than the usual surface usually recommended per horsepower; that is, for a horizontal tubular, 12 square feet, and for water tubular, 10 square feet.

In regard to the area of grate surface per horsepower the committee recommends the following: (1) Run of mine, $\frac{1}{6}$ to $\frac{1}{5}$ square foot per horsepower; (2) slack, bituminous anthracite, $\frac{1}{4}$ to 5 square feet per horsepower, the air space in the grate being taken at 50 per cent. For mechanical stoking the rate should be the same.

Regarding the third matter, the committee finds that in all cases the draft should be measured not in the stack nor in the ash pit, but in the furnace over the fire and with the furnace door closed and the ash-pit door open when working the grate at the above-mentioned rate. When thus measured in unfavorable weather the minimum should be $\frac{3}{8}$ inch for run of mine and $\frac{1}{2}$ inch for slack.

Regarding smoke prevention the committee reached the following conclusions:

1. In an ordinary furnace smoke may be made very light by careful hand firing, yet in practice this cannot be obtained con-

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tinuously, and the use of special furnaces or appliances should be insisted on and made compulsory by law.

2. The best method of preventing smoke is to burn the fuel in a separate chamber, so that the combustion is complete before the gases touch the surface of the boiler.

3. Where this method is not practical, as in boilers already set, and where there is no room, the best results are obtained by mixing the smoke, as it passes from the furnace, with heated air, the effect of which increases the temperature of the smoke as the temperature of the air increases, thus burning the smoke.

4. That as, even with special furnaces of the above types, with hand firing, the combustion is irregular and hence some smoke must be produced at times, the use of mechanical stokers is strongly recommended, especially in all plants above 100 horsepower.

5. As mentioned above, there is a lower limit of grate area per horsepower, below which the furnace is not heated enough to insure complete combustion and smoke is thus produced. For this reason all plants should be subdivided into two units at least, in order that the boilers may never run at a lower activity than one-third of their rated horsepower.

FOUR IMMENSE DRY DOCKS—LEAGUE ISLAND, MARE ISLAND, BOSTON AND PORTSMOUTH.

Under the direction of Rear Admiral Mordecai T. Endicott, the Bureau of Yards and Docks has now under way or plans prepared for the construction of four dry docks—League Island dry dock, Mare Island dry dock, Boston dry dock and Portsmouth dry dock. The first two named are to be of timber and the last two of concrete and masonry. Each pair considered in itself is almost identical; and therefore a description of one is a description of the other. Reference is first made in the following paragraphs to the League Island dock.

There has been much criticism because the League Island dock is to be built of timber. The Bureau itself is in favor of a concrete and masonry dock, but the specifications prepared by Con-

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gress provide for timber. The recent collapse of the New York dry dock, however, has given the country a warning, and considerable influence will be brought to bear upon Congress to change the specifications. The Government, therefore, reserves the right to modify the construction of the dry dock from one of timber to one of concrete and stone, should Congress so authorize, and in the event of such a change being made the Government will reimburse the contractor for the increased outlay in cost. Bids were recently opened for the construction of the League Island dry dock, but the Bureau has deemed it expedient to reject them all.

The most popular description of a dry dock is to say that it is a coffin-shaped hole in the ground lined up with timber and fastened to piles. Piles are driven at accurate spaces at the bottom of the excavation, and the evidence of their security lies in the fact that at the last blow of the hammer, weighing 3,000 pounds and falling 25 feet, the penetration shall be not more than ½ inch. Transverse timbers are then put on top of the piles and longitudinal timbers on top of the transverse and then a flooring of 3-inch planks. All of the transverse timbers are to be in not more than three pieces, securely fastened together with scarfs and bolts. On top of the timbers rest the keel blocks, spaced 4 feet apart, and on the side are the bilge blocks, spaced 16 feet. The heads of the foundation piles will be surrounded by a continuous bed of concrete at least 3 feet thick and extending up the sides in the body of the dock to the foot of the fifth altar.

The whole flooring will be surrounded by sheet piling and in the sides of the excavation inclined piles will be driven, and to these will be fastened the braces which carry the sides of the dock. These sides are composed of altars which have 11 inches rise and 9 inches tread, making a continuous stairway from the coping to the floor. The sides of the dock also have timber slides for sliding material down from the top to the bottom, and at each slide is an electric capstan for letting the material down into the dock. The caisson, or floating boat gate, of the dock, will have eight watertight compartments arranged for flooding or emptying as desired, thereby making it a floating or sinking

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structure. It contains its own power for flooding or emptying its watertight compartments and operating the capstans and other mechanism. It will be built of open-hearth steel and will maintain an even keel under all conditions of flotation or submergence. Dimensions of the caisson are: Length, extreme, 106 feet $8\frac{7}{16}$ inches; breadth molded, 22 feet; depth from bottom of keel to underside of upper deck at the side, 37 feet 9 inches. The hull of the caisson will be fitted and completed with centrifugal pump, locomotive boiler, vertical engine, feed tank, capstans, trimming tanks, gate valves and culverts, drains, hatches, air pipes, concrete and movable ballast, bitts, deck cleats, scuppers, aprons, air ports, stanchions and guard chains. The caisson will contain 509,000 pounds of structural steel and 596,700 pounds of concrete for stable flotation.

To pump out the dock a large centrifugal pumping plant will be established and will be driven by electric motor with power supplied from a general power station. The pumps will be situated in a circular well, about 53 feet in diameter, with floor level of pump well about 36 feet below the level of the ground. The pumping plant will consist of three centrifugal pumps for pumping out the dock, with separate motors, all independent, and one centrifugal drainage pump and motor. These pumps admit water on both sides of the runners and give a discharge of 43,000 gallons a minute for each pump.

The only distinguishing difference between this dock and the one at Mare Island is that the Mare Island pumps will be driven by steam. General dimensions of the League Island dock are:

Length on coping from head to outer-gate sill, feet	750
Length on floor from head to outer-gate sill, feet and inches	717– 9
Width on coping in body, feet and inches	144– 6
Width on floor in body, feet	80
Width on coping at abutment, least, feet and inches	104– 3
Width at entrance on mean high-water level, feet	101
Depth from coping to mean high water, feet and inches	6– 6
Depth from coping to floor in body, feet and inches	40– 3
Draught over sill at mean high water, feet	30

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PORTSMOUTH, N. H., AND BOSTON DRY DOCKS.

No piling whatever is contemplated for the Portsmouth dry dock. The bottom and sides will rest on solid rock, which has to be blasted out. This dock will doubtless be one of the most stable things in Christendom. The stone masonry of the body of the dock will consist of granite. The bottom and sides will be composed of granite and the interior lined with granite ashlar. The stone masonry of the walls and entrance will be ashlar in continuous courses, and is to be rough pointed on the face and fine pointed on altar treads and on floor. The altar system will be different from that of the League Island dock, having deep altars of 4 feet with the lower portion made up of a number of low altars.

The keel blocks, bilge blocks and bilge-block slides are to be of white oak, and all fittings for them will be of composition. They are to be spaced the same as in the timber docks. The entrance to the dock will be closed with a caisson or floating gate. The change of shape is slight, the corners being rounded off, while in the timber dock they are not.

The pumping plant, which is almost identical with that of the League Island dock, will be driven by an electric motor with power supplied from a central power station. To facilitate the hauling in of the ship and the handling of her while she is being docked, there are placed at the entrance of the dock and at the head three electric winches and along the side, at each timber slide, is placed an electric capstan, and bollards are spaced at intervals about the dock.

The Boston dock differs from the Portsmouth dock only in that it is built upon compacted clay with heavy concrete foundation. Dimensions of the Portsmouth dock are:

Length on coping from head to outer-gate sill, feet	750
Length on floor from head to outer-gate sill, feet	725
Width on coping in body, feet	130
Width on floor in body, feet	80
Width on coping at abutment, least, feet and inches	101– 9
Width at entrance on mean high-water level, feet	100
Depth from coping to mean high-water level, feet and inches	5– 3
Greatest depth from coping to floor in body, feet and inches	39– 3
Draught over sill at mean high water, feet	30

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The Boston and Mare Island docks are now under way and bids are being solicited for the Portsmouth and League Island docks. These docks, when completed, will accommodate the largest thing afloat, including the auxiliary cruisers and the monster *Oceanic*.

The following is a table showing the United States naval docks already in existence:

UNITED STATES NAVAL DRY DOCKS.

Character.	Station.	Material of construction.	Length on floor.	Width of entrance at coping.	Depth over sill at mean high water.
			ft. ins.	*ft. ins.*	*ft. ins.*
Balance	Portsmouth, N. H.	Wood	350- 0	90- 0	25- 0
Graving	Boston, Mass.	Granite	367- 5½	60- 0	24-10
Graving	New York, N. Y.	Granite	338- 3	66- 0	25- 3
Graving	New York, N. Y.	Wood	459-10	85- 0	25- 6
Graving	New York, N. Y.	Wood	626- 8	105- 2⅞	29- 0
Graving	League Island, Pa.	Wood	459-10	85- 0	25- 6
Graving	Norfolk, Va.	Granite	302- 9	60- 0	25- 0
Graving	Norfolk, Va.	Wood	459-10	85- 0	25- 6
Graving	Port Royal, S. C.	Wood	459- 0	97- 0	26- 0
Graving	Mare Island, Cal.	Granite	459- 0	80- 6⅞	27- 6
Graving	Puget Sound, Wash.	Wood body, masonry ent.	618- 6	92- 7⅞	30- 0

—"Marine Review."

The "Engineering News" of September 28th states that the Portsmouth, N. H., stone dry-dock contract has been awarded by the Navy Department to John Peirce, of New York, for $1,089,000. Mr. Peirce owns the granite quarries at Frankfort, Me., and he is President of the company owning the Hallowell, Fox Island and Stoney Creek granite quarries, also in Maine. Work is to begin within 60 days and the concrete dock is to be lined with about 600,000 cubic feet of cut granite.

ALGIERS FLOATING DRY DOCK.

The floating dock which is now under construction by the Maryland Steel Co. at Sparrow's Point, Md., and which is to be

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stationed at Algiers, La., is the largest floating dry dock in the world and is designed to dock the greatest battleship or armored cruiser afloat. It will lift a ship of 15,000 tons. At present the Government has no ship in its service of that tonnage, but it is quite likely that within a very few years it will have. The dry dock is therefore being built for the future.

The dock itself consists of five pontoons, comprising three pontoons which form the main lifting portion of the dock and two side walls which serve to give the dock stability. The pontoons themselves are of different size and form. The center pontoon, which is 240 feet long, is rectangular in shape, but the terminal ones have each only 80 feet 6 inches of their length rectangular, the remainder being finished off in the form of a bluntnosed point or bow. For a length of 55 feet these pontoons are also buoyant, but the remaining or outside 30 feet, forming the point proper, is formed by a series of plates and lattice girders of strong construction that support the ends of a ship without at the same time giving any buoyancy to the ends of the dock when short vessels are placed thereon. These end platforms have, however, the deck plating watertight, and are surrounded by watertight bulwark, which runs around the whole of the end of these pontoons.

The pontoons of the dock are divided into thirty-two pumping divisions, of which twenty-four are absolutely watertight and distinct. The sidewalls have each four watertight divisions. All these forty divisions are provided with a separate pipe, each governed by a separate valve. All the pipes in the starboard half of the dock are led directly into the main drain in the starboard wall and all in the port half to a similar drain in the port wall. These drains are continuous over the whole length of the walls, and the four pumps in each wall are seated directly in them so that any one pump can empty all the compartments of its half of the dock. In the event of a breakdown of a half the other half could empty the whole deck.

A separate engine is provided for each pair of pumps and a separate boiler for each engine. The steam pipes are, however, so arranged that either engine can take its steam from either

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boiler. This duplication prevents a complete breakdown. Steam is the only motive power used in the dock. Although the dock is divided into forty sections, each with its own regulating valve, the work of the whole dock is done from two central positions on the top of the towers. Each valve house is in direct communication by speaking tube with its engine rooms, so that the man in charge can manipulate every valve, both water and steam, for the maneuver of the dock without quitting his post.

The dock floats at a draught of 4 feet. The valves are opened and the dock sinks bodily. It sinks to such a depth from floor line to top that it will take a ship of 30 feet draught, leaving it only 4 feet out of water. The dock is built of steel plate and angles. Great care must be exercised to see that the ship centers on the keel blocks. Then the pumps are set to work and the water is pumped out of the watertight compartments. The operator must see to it that the dock remains perfectly level. This can be regulated by shutting off a pump and leaving water in as a counterbalance. The watertight compartments have great value in controlling balance. Having seen that the keel of the ship and the keel blocks are even, as the boat comes out of water shores are put in place to give additional steadiness to the sides of the ship. When the deck of the pontoon is 2 feet out of water the surface of the ship is actually 6 feet out of water when one gets ready to work on it.

One of the great features of the dock is its self-docking qualities. Provision had to be made for this, for like any other vessel it could get out of repair and there is no dock in the world large enough to receive it. If one wants to dock the middle pontoon, the lugs and fish plates are disconnected and the pontoon is allowed to float loosely. The pumps are disconnected and the opening closed by valves. Then water is admitted to the side walls and the middle pontoon floats up. The side walls are sunk until the lug at the bottom of the middle pontoon corresponds to an upper lug on the side wall. The middle pontoon is therefore entirely out of water and access can therefore be had to any part of it. The middle pontoon has sufficient capacity to dock both ends at once. One of the side walls can be tilted out of

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water by filling the other side. The dock is entirely complete in itself, with engines, boilers and quarters for crew, and is anchored just like a ship. It can be towed anywhere. It will be towed to New Orleans, and stationed at Algiers.

This floating dry dock will be a particularly valuable feature in case of war, for it will dock the largest battleship. Had it been built at the time of the Spanish-American war it might have resulted in the saving of the *Maria Theresa*. The dock is 525 feet long and 52 feet high, and has a clear width between walls of 100 feet. Its lifting capacity is 15,000 tons.—"Marine Review."

GAS ENGINES FOR SHOP DRIVING.

The rapid and substantial advancement of the gas engine as a power producer for machine and generator driving will surprise those who examine its present status with a view of using it to replace steam. By many who are not informed as to its progress it is regarded as too experimental and too uncertain for consideration as a source of power for running machines which must work every day and must not be stopped for breakdowns. The gas engine is very far from perfect, but it has now reached a stage which warrants its consideration as a reliable motor which is cheaper than the steam engine in fuel cost and attendance, and in addition to these advantages it offers a means for subdivision of power that is equal in efficiency, if not superior, to that of electricity.

The reliability of the internal combustion engine is proven by those that are running all day long without stopping, and many are running in buildings which are closed and locked, except when the attendant comes to oil them. A 65-horsepower Westinghouse gas engine has made a wonderful record for long continuous running, which has probably not been approached in severity by any steam engine running in regular service. The one referred to is in New York City, and from October 15, 1898, to February 28, 1899, it averaged 22.3 hours running per day for 137 days. During this time it was idle but 230 hours, and only 49 of these were required in repairs to the engine. We are told

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that 26 hours were spent in replacing the igniters with new ones, and 12 hours were given to the bearings and adjustment of other parts. A continuous run of 638 hours, ending February 19, is recorded. It is not necessary to say more with regard to reliability, because that engine was working under conditions more exacting than are usually confronted by steam engines.

The gas producer furnishes means for operating gas engines independently of city mains, and oil or distillate may be used where it is difficult to secure appropriations for the gas plant. The attendance required for a gas producer is less than for a boiler, because the operations are almost entirely automatic. Mr. A. R. Bellamy gives valuable records from the daily operation of a plant in England, including two 40-horsepower gas engines driven by producer gas. Two-thirds of a cent per indicated horsepower hour cover all charges for operation, where anthracite coal costs $6.25 per ton. The producer makes 1,000 cubic feet of gas from 14 pounds of coal, including all losses, and the two engines, the producer and a steam boiler (for operating steam hammers), were attended by one laborer. The same expense for attendance would be ample for double this amount of power. The engines in this case are looked after by an uneducated man, who gives them less than two hours per day. The cost of the gas may be placed at 6½ cents per 1,000 cubic feet. The consumption of fuel is 0.939 pound per indicated horsepower per hour, including all losses, and against this may be placed the wasteful single-expansion steam engine with disgracefully long steam pipes. It is well known that many such engines have been struggling for years at an expense of from five to eight pounds of coal per indicated horsepower hour.

Mr. Bellamy records valuable figures for electric lighting. The power used in the case cited is 18 brake horsepower. At 83 cubic feet of fuel gas per brake horsepower hour and an average of 20 hours per week, the cost was less than ten cents per hour for 38,000 candlepower in arc lamps and 496 candlepower in incandescents. The efficiency attained by the Westinghouse gas engine, as reported by Mr. Edwin Ruud, for engines of 20 horsepower and upward with natural gas is from 10.5 to 12 cubic

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feet per brake horsepower hour and a special 125-horsepower engine has given the phenomenal economy of one brake horsepower for 9 cubic feet. This gas gives 1,000 British thermal units per cubic foot, and the best record is an efficiency of 28.7 per cent., while 33⅓ per cent. is promised for every-day performance.

The figures for the operation of oil engines, including all charges, are not available for comparison, but we have Professor Denton's authority, based on a test of a 20-horsepower Diesel motor, expressed in his report as follows: "As the motor shows itself to be able to use oil obtainable at about two cents per gallon, the cost of a brake horsepower may be two-tenths of a cent per hour, which is slightly less than the cost of the same power from the average triple-expansion steam engine, with coal at $3 per gross ton."

The proposition before a shop manager who is planning improvements or entirely new shops is this: Will it be a good investment to install a gas-engine equipment for the entire power plant, put in a gas producer and also provide a steam plant for heating in the winter? The man who does this may be considered bold, but he has excellent precedents and will undoubtedly save money by it. The gas producer may be run when needed, and by providing sufficient storage no gas need be made when only a part of the engine equipment is running.

This simplifies night work. The subdivision of power by gas engines is easy and economical, and gas fuel may be distributed much more easily than power. Quoting Mr. Bellamy again: "One horsepower at the gas plant is sufficient to force through mains one mile long, sufficient to supply 3,000 horsepower. It is probable that in certain cases it will be cheaper to run small outlying shops of a large plant by gas engines than to drive by electric motors from a steam-driven generator."

A little study of existing records reveals a most promising prospect for the internal-combustion engine, whether the fuel is oil or producer gas, and the outlook for producer gas made from the cheapest forms of anthracite, down to the size known as buckwheat, is exceedingly bright. The illustrated descrip-

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tion of the producer and gas-engine plant at the Jersey City terminal of the Erie R. R. in this issue is worthy of thoughtful attention in this connection.—"American Engineer and Railroad Journal."

EFFICIENCY OF WATER-TUBE BOILERS.

The discussions which have taken place in Parliament and in the daily press on the subject of water-tube boilers, have been chiefly instrumental in demonstrating the ignorance of novel conditions of those who opposed the new system. Many, if not the most of them, have written as if the subject of debate were the relative merits of the Scotch and the water-tube boilers. Now, on that matter, we imagine, there is no doubt. From the point of view of the seagoing engineer, the Scotch boiler is far away the better of the two, so long as it is not forced. But it is just this last condition which cannot be secured. The naval tactician demands speed, while the naval architect can only allow the engineer a very moderate portion of the displacement for his engines and boilers. Hence, each ton of boilers must be made to furnish more steam than it does on board a merchant ship. If our ocean liners had one-third of their boilers taken out, and were still required to make their usual speed, they would be pretty much in the position of Her Majesty's fleet when it is ordered to go at full speed. The relative conditions of naval and mercantile vessels are well shown in a Parliamentary return issued some little time ago by the Admiralty. In this, ships fitted with water-tube boilers are compared with similar vessels having cylindrical boilers. In a table referring to battleships we find that the average of vessels containing cylindrical boilers, built after the Naval Defence Act, gives 7.8 indicated horsepower per ton of machinery, complete with boilers, for natural-draft trials, whilst each ton of weight of boilers complete (exclusive of engines) gives 14.4 indicated horsepower. In other words, the weight for each indicated horsepower developed is 132 pounds for engines and 156 pounds for boilers, giving a total of 288 pounds weight of machinery to produce each unit of power. If we compare this with the average

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of that of six ships of the *Canopus* class, fitted with Belleville boilers with economizers, we find that when developing the natural-draft power, 10.5 indicated horsepower per ton of machinery complete was developed, whilst for each ton of boilers complete 21.7 indicated horsepower were developed.

Taking the figures in the other way to correspond with those already quoted, we find the weight for each unit of power developed was 111 pounds for the engines and 103 pounds for the boilers, giving a total of 214 pounds of total weight of machinery for each indicated horsepower. The comparison is not, of course, complete; the sizes of the engines were different and the pressures also were not the same. In the case of the cylindrical boilers the total power exerted by the machinery in the instance quoted was a little over 6,000 indicated horsepower, with a power similar to that exerted in the case of the Belleville boilers the figures as to weight come closer together, but the cylindrical boilers then had a pressure of 0.27 inch of air for urging the fires. Of course comparisons such as these may easily lead to erroneous conclusions, but we take it that the Admiralty engineers design machinery most suitable for the ship, and, if we allow this, the comparison is strongly in favor of the water-tube boiler, supposing the assumptions are borne out, as they doubtless will be.

In the case of the battleships, the coal consumption of the vessels of the *Canopus* class is naturally not given; but in a second table, in which first-class cruisers are dealt with, we have a column "Coal per Indicated Horsepower per Hour." It is, of course, in coal consumption that the water-tube boiler is most open to attack by its opponents. The Admiralty return, however, hardly supports the contention. Running down the table of coal consumption of first-class cruisers, we find that with the cylindrical boiler the best consumption quoted is 1.70 pounds of coal per indicated horsepower per hour. This is practically equalled by the *Terrible's* record of 1.71 pounds, and several other ships fitted with Belleville boilers show almost the same figure. It is, however, exceeded in value by that of the *Diadem*, which burnt only 1.61 pounds of coal per indicated horsepower per hour. The *Niobe* gave even a better figure; her best record being 1.55 pounds,

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whilst the *Amphitrite* heads the list with 1.43 pounds of coal per indicated horsepower per hour. The latter, we think, is the best record that has been obtained with any vessel in Her Majesty's Navy. At any rate, it is the best in the return under consideration.

There is another point to which we would make reference in touching in a cursory manner on this question of Navy boilers. It is the fashion of some who pretend to instruct the public in these matters to write as if no accident ever happened to a cylindrical boiler, and there were no defects in its design and economy. It is needless to remind our engineering readers of the difficulties that arise with cylindrical boilers with the admission of salt water. But one would think, to read what has been written lately, that ordinary shell boilers were fed with nothing but salt water. We would refer those who hold that the smallest drop of salt water will immediately destroy a water-tube boiler, to the speech of Mr. Wingfield, made at the summer meeting at Newcastle of the Institution of Naval Architects. This gentleman, who is certainly a good authority on the subject, told us that not only may water-tube boilers have a certain proportion of salt water mixed with the feed, but that one vessel made a large part of the voyage to South America wholly with salt-water feed, and it should be remembered that these boilers were of the Express type, having small and bent tubes, a form which is considered by some eminently unsuitable for evaporating salt water. Of course, it is needless to tell engineers that no one puts salt water in his boiler, in these modern days of high pressures, if he can help it. No matter whether it is a cylindrical boiler or a water-tube boiler, there are tubes in each, the surfaces of which it is eminently undesirable to deteriorate with a coating of scale. But in the cylindrical boiler there are furnace crowns to come down, a matter so far more serious than the bursting of a tube, that it is more incumbent on the engineer in charge of shell boilers to avoid scaling than it is for the attendant on a water-tube boiler; that is, so far as safety is concerned.

We need not, however, labor this point. It is highly improbable that the old cylindrical boiler will again find its way into

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warships, unless under exceptional circumstances. We cannot expect that there will be no further boiler accidents, even, unhappily, there may be some of a fatal nature. Dreadful as it is to contemplate loss of life and mutilation to human beings, yet that cannot stand in the way of the development of our Navy, which is the guarantee of our existence as a Nation. Not long ago we had in rapid succession two serious accidents in the engines of war vessels; one of these proved of a terribly fatal nature, and, though no life was sacrificed, through the first mishap, that was owing to good fortune, if such can be said in the case of men so terribly injured as those were through the first accident. No one, however, will suggest—certainly not the men of the Royal Navy, who are most liable to these accidents—that on this account we should abstain from building an undeniably delicate and intricate, yet most effective class of vessels; we refer, of course, to the torpedo-boat destroyer.—"Engineering."

THE ATBARA BRIDGE.

On April 20 last Sir Alfred Hickman, in the House of Commons, asked the Under-Secretary of State for Foreign Affairs for information as to the circumstances under which the contract for the Atbara Bridge was given to an American firm. No reply to the various questions was possible at the time, but they now appear in the form of a Government paper of unusual interest, and although the complete story was told by us some time since we return to the subject now that the official narrative is made public. The control of the Atbara bridgework was in the hands of Lieutenant-Colonel Gordon at Cairo, his agent in England being Colonel Western. As everyone knows, the Sirdar had, with characteristic energy, pushed forward a railway into the desert on the bank of the Nile, its immediate purpose being to aid in the great campaign, and its ultimate object, a terminus at Khartoum. The Atbara River interposed a serious obstacle, and the line could not be completed without a bridge, the erection of which was of extreme urgency. So urgent indeed was Lord Kitchener's requirement that he requisitioned for stock

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material that would serve the purpose forthwith. Of course, this was not forthcoming, and plans and specifications were immediately prepared.

This was in October of last year, and on December 29 following, tenders for the work were received in Cairo. Seven offers were sent in, five from English, and two from American, firms; the prices per ton of the latter were 11l. 17s. 6d. per ton, and 13l. 11s. 6d. per ton; the English offers ranged from 16l. 12s. to 13l. 10s. per ton, in all cases, both English and American, with delivery at Liverpool. The time required varied from fourteen weeks to nine months. A mistake, however, had been made in the design of the bridge, which involved the necessity of heavy false works in the bed of the river—a condition which could not be accepted. Fresh tenders were, therefore, asked for, from the same firms, who were furnished with a very rough specification, the two necessary conditions being quickness of delivery, and erection by launching without any false works; price was altogether a secondary consideration. The specification was as follows:

"Provide for a train of two engines (as per diagram)* followed by train of 1 ton per foot run.

"Wind, 30 pounds on a train 11 feet high above the rails, plus the girder surface.

"Limiting stresses, 9 tons per square inch on net sections, calculating the working load as follows:

"Dead load plus live load by 1.5.

"Provided that the dead load assumed shall never be less than half the live load.

"The bridge is to be a through bridge, 14 feet clear width and 15 feet 6 inches headway, of seven spans of 150 feet clear, carried on cylinders 10 feet in diameter, the girders to be launched, but the continuity is not to be permanent. Launching strains not to exceed 9 tons."

From the foregoing it is evident that manufacturers were left an entirely free hand as to design, subject, of course, to the ap-

* See "Engineering," Vol. lxvii, page 770, Fig. 5.

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proval by Colonel Gordon or his colleague, Colonel Western. From the commencement of the negotiations it appeared quite hopeless to expect anything like an early delivery from the English manufacturers, a delay of, at first, one year before completion in England, and afterwards of two years, being the conclusion unavoidably forced on the authorities. Nor were the two offers coming from America satisfactory as to early delivery. Colonel Gordon accordingly caused further inquiries to be made in America, and in consequence obtained an offer from Pencoyd (the first appearance of that company in the matter), guaranteeing delivery of a standard-type bridge in six weeks. This offer was shortly after modified in accordance with the specification quoted above, and on January 25, last, the revised results were in the hands of Colonel Western; they were as follows:

Phœnix Company, declined for early delivery.

Horseley, declined for early delivery.

Handyside, declined for early delivery.

Patent Shaft and Axle Company, 15l. 15s. per ton in English port, first span in two months; the others, one every three weeks.

Sanders, Pennsylvania, 10l. 15s. per ton United States port; time, three and one-half months.

Union Bridge Company, 13l. per ton United States port; time, sixty-five days.

Roberts, Pencoyd, $31,000 United States port; time, forty-two days.

Certainly Colonel Gordon spared no pains in giving every facility to English manufacturers, but competition was entirely out of the question. Colonel Gordon states in his report that one of the directors of the Patent Shaft and Axle Company, which had done all that was possible to secure the contract, called on him in Cairo, and asked what the result had been. "When I told him that we had placed the order with Pencoyd for complete delivery in six weeks, he told me that they could not possibly compete against such quick delivery, and that he doubted whether any firm in the United Kingdom could make as good an offer as they made (the Patent Shaft and Axle Company), as they were, he believed, the only firm in the United Kingdom that rolled

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their own material, all the bridge makers having to depend for their rolling on outside firms, who might or might not be able to give preference to this work."

We have already given in full detail the story of the rapid construction of the Atbara Bridge in the shops of the Pencoyd Company; the last shipment was made on March 15, well within the time guaranteed by the makers.

The statements of Colonel Gordon effectually dispose of the absurd stories of favoritism to American makers, which have been circulated to excuse the deficiencies of our own manufacturers, while the equally absurd statement that while English makers were bound down to follow a prescribed design, Pencoyd was given a free hand, is also effectually contradicted. On the other hand, the opinion expressed by the director of the Shaft and Axle Company quoted above, must, we suppose, be accepted as correct.

We have seen that the question of the price paid for the Atbara Bridge was of very small importance; but it is of interest to compare the offers made by the Patent Shaft Company and Pencoyd. The price of the former was 15l. 15s. per ton delivered in an English port; the latter was a lump sum of 32,000 dollars, or, say, 6,400l. delivered at New York. The weight of the Pencoyd Bridge, including erection plant, was 1,507,000 pounds, or, say, 670 tons, making the price per ton 9l. 11s. To this has to be added freight to Liverpool, 1l. 2s. 6d., bringing the cost per ton to 10l. 13s. 6d. On this point Colonel Gordon says: "The price quoted by the nearest English firm was 10,400l. I may mention that this was calculated on the weight of the English bridge being the same as the American, but I now gather that it would have been about 200 tons more, and, at 15l. 15s. per ton, would mean an increase of 3,150l." It has been urged that the Pencoyd Company took the contract at a loss, but this is not so, and we notice that, even with the present great inflation of prices, they have secured a 10,000-ton contract for Japan at 15l. per ton.

It will be observed that the contract for the Atbara Bridge referred only to the superstructure, which rests on cylinders sunk under another contract. With reference to this, Colonel Gordon's report contains the following suggestive paragraph:

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"I wonder that comment has not been made on the fact that the more expensive portion of the bridge was contracted for by an Italian firm, the answer to this being that there is only this single firm in Egypt possessing the required plant for sinking cylinders, &c.; and until a British firm sets up a plant in this country, I conclude that all bridges whose substructures are built as those of the Atbara and others will continue to be contracted for by this firm."—"Engineering."

CRYSTALLIZATION AND SEGREGATION OF CAST IRON.*

Mr. West has pointed out very clearly in his paper that the present method of selecting pig iron by fracture is defective and misleading. How is the structure formed which we see on breaking a pig? A molton mass of iron in the blast furnace, cupola or ladle is a combination of chemical elements, held in solution by the fluid mass of iron, just as salt or sugar is held in solution by water.

Each of these elements has a different melting point and point of cooling. Some of these elements are attracted to each other, thus forming a combination. As soon as the iron gets cool enough, crystals begin to form and try to extract out of the surrounding fluid metal all the elements necessary to their growth. The crystals grow as long as they have an opportunity to extract material for growth from the fluid iron surrounding them. Hence, if we cool iron quickly, we stop the crystals' growth while they are small. This is clearly shown by the samples exhibited here by Mr. West. The pieces of small cross-section have a fine structure, because they cooled quickly and the crystals had no time to grow larger. The larger sized sections have a coarse grain, because they had more time to grow, due to slow cooling. The fractures of the test bars exhibited by your committee on "Standard Tests," show the same phenomenon.

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* Extract from discussion of a paper on "The Deceptive Fracture of Pig Iron," by Mr. Thos. D. West, read before the American Foundrymen's Association. (See "Eng. News," May 25, p. 340.)

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A couple of years ago I came across a very striking instance of the effect of time on cooling, on crystalline structure of iron and steel. A large part of the contents of an open-hearth furnace escaped through the bottom of the furnace. The bottom was repaired and the metal was left there until the furnace had to be torn down. Here was an opportunity for the escaped fluid metal to cool very slowly. As a consequence the crystals in that mass of soft steel were of extraordinary size. I obtained a well formed crystal, which measured 1⅜ inches, in length and ⅝ inch in width. I have still a piece of that metal with a crystal imbedded, measuring ⅝ inch. Ordinarily the crystals of such steel in the ingot measure only a few hundredths of an inch.

Such an instance furnishes proof of the importance and influence of time in cooling a molten mass of iron on the size of structure, irrespective of chemical composition. You can readily imagine the gradations in size of structure, due to time of cooling, between the crystal 1⅜ inches long, and the fine structure we might be able to obtain in the same metal by instantaneous cooling of the mass. For the same reason, an iron low in silicon may have as coarse if not a coarser fracture, than an iron high in silicon and graphitic carbon.

There is another property of cast iron with which foundrymen are much concerned, but which thus far has not received the attention it deserves. Cast iron is an alloy composed of iron and other substances. Now the melting point of alloys varies with their constitution. Thus wrought iron melts at 2,912 degrees Fahrenheit, gray iron at 2,280 degrees Fahrenheit, and white iron at 2,075 degrees Fahrenheit. An alloy of 1 part tin and 25 parts lead melts at 558 degrees Fahrenheit, while an alloy of 6 parts tin and 1 part lead melts at 381 degrees Fahrenheit. The melting point of tin alone is 451 degrees Fahrenheit and that of lead is 618 degrees Fahrenheit. Naturally, an increase in the number of elements in an alloy and variations in the percentages of elements will produce complications in the melting points of alloys. These complications are increased by the law of affinity, according to which certain elements will attract each other and combine with one another more readily than other elements.

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They will flock together like birds of a feather, as the saying is. It must be obvious that, during the formation of such complicated combinations the rate of cooling again plays an important part.

But to fill the foundrymen's cup of bitterness and perplexities to overflowing sometimes, and to make him scratch his head in wonderment as to what will come next, there is the phenomenon of segregation in alloys, and cast iron is much affected by this phenomena. Iron, like water, has the ability to dissolve and hold in solution foreign substances when in a fluid state. But when a fluid mass of iron cools down to the point of solidification the foreign substances, held in solution while the iron was fluid, segregate out of the iron, one after another, the same as salt segregates out of the water, whenever there is more salt dissolved in a hot brine, than the water can hold when cold. Now the iron can hold more carbon, silicon, etc., chemically combined, when in a fluid state than it can hold in a solid state. Consequently, when a molten mass of cast iron freezes, such of the foreign substances held in solution by the molten iron as cannot be held by the solidified iron, will segregate out during cooling until the mixture reaches certain proportions. The mixture with these proportions which freezes last, is called the mother metal, in alloys of metal, and the mother liquor, in other mineral solutions, for cast and pig iron are nothing but mineral solutions after all.

According to Roberts-Austen and Jueptner von Jonstorff, the mother metal of cast iron is composed of 95.7 per cent. of iron and 43 per cent. of carbon. The mother metal of an alloy of copper and silver contains 28 per cent. of the copper and 72 per cent. of silver. Whenever, therefore, in an alloy, an excess of elements is present above the proportions necessary to form the mother metal this excess will separate, or segregate out of the molten mass, and solidify before the mother metal freezes or solidifies.

This is the reason why a plumber can make a wiped joint. If he would take a mixture of lead and tin, or whatever metals he uses, of such proportions as just to form the mother metal of a

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tin-lead alloy, he could not make a wiped joint, because his mixture would solidify under his hands so quickly that no time would be left to wipe the joint. Having an excess of lead, however, this excess freezes first and continues freezing while the plumber is wiping the joint, until so much of the lead has frozen, or segregated out of the mixture, as to leave the proper proportion of metals to form the mother metal. When that point is reached the whole of the mixture freezes at once without any further segregating out of the one or the other metal.

Now this same action takes place in cast iron, or other alloys, and this segregating out of the excess of elements in alloys, over and above those proportions necessary to form the mother metal is a disturbing factor of unknown influence in the brass and iron foundry. On account of this, cast iron has two cooling points, instead of one. In other words, the excess of elements present, over and above the mother metal, solidify or freeze, first and at a higher temperature than the mother metal. For instance, a mixture of cast iron with 98 per cent. of iron and 2 per cent. of carbon will solidify at 2,408 degrees Fahrenheit; but if the iron is given time enough to cool slowly for the segregating out of the excess of iron over and above 95.7 per cent. of iron and 4.3 per cent. of carbon, which is the mother metal of cast iron, than that iron will solidify at two different temperatures, viz: the excess at about 2,408 degrees Fahrenheit, and the rest at 2,066 degrees Fahrenheit, which is the freezing point of the mother metal of cast iron. According to Charpy, bronzes may sometimes have three, or even four, freezing points.

The practical lesson for the foundrymen from all this is that if he knows he has the right mixture for a given purpose, to try and pour his iron at a sufficiently low temperature to prevent segregation as much as possible in large castings. Under unfavorable conditions such segregated castings, notwithstanding their chemical composition is all right, may be weak, because of the want of homogeneity of the structure. The casting may appear solid enough, but when a casting happened to solidify at two different temperatures, the structure or grain cannot be uniform throughout the mass, and there is liability to lines of weak-

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ness running through the casting between the juncture of patches of coarser grain and finer grain.

We can thus readily see that it is not always the chemical composition alone that secures a good, strong and sound casting. We can also imagine what possibilities there are in alloys in general, and cast iron in particular, for the formation of an endless variety of combinations and complications due to this peculiarity of segregation in alloys of metals, and the greater the number of elements present the greater the liability for complexities.

INDIA AS A CENTER FOR STEEL MANUFACTURE.

[By Major Reginald Henry Mahon R. A. (Cossipore). Paper read before the Iron and Steel Institute, Manchester meeting.]

The object aimed at in this paper is to place before members of the Iron and Steel Institute facts relating to the possibility of manufacturing at a profit iron and steel in India.

If it can be shown that suitable material can be collected and worked into steel at a given center in India at a price not exceeding similar manufacture in Europe or America, it must then be conceded that such steel starts in the markets of the East with an advantage equal to the freights charges on imported material. This advantage would never be less than 12s. a ton, and would rise at times to 18s. There would, however, fall to be deducted from this the freight charges from the selected center to other ports; this deduction could not under any circumstances absorb the whole. The cost of the Suez Canal passage (say, 4s. per ton), and some gain due to decreased lead, must ever be on the side of local produce, even when distributed under the most unfavorable conditions.

India alone, as a market, is capable of taking a very large quantity of manufactured steel, and its requirements are certain to increase for a number of years. In the year 1897–8 the imports of rolled iron (including plates) was 137,000 tons, a very large part of which would be accepted in mild steel. During the same period rolled steel, excluding rails, was 80,000 tons; rails and fish plates amounted to 93,000 tons more. In addition

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to this, 30,000 tons of pig iron and iron pipes were imported, and 43,000 tons of iron and steel sleepers. The sum total of these figures is 383,000 tons. Machinery and rolling stock for railways was also imported to the value of about 40 million rupees (about 2½ million pounds). Of the entire quantity of iron and steel imported into India, one-third of the iron and one-half of the steel comes from countries other than the United Kingdom.

The coal output has quadrupled during the last ten years, and now amounts to over 5,000,000 tons annually. The average cost price at the pits is Rs. 2 per ton (2s. 8d.). The greater part is good steam coal, and a coke can be made from it which is singularly free from sulphur (0.5 per cent.), and contains from 10 to 12 per cent. of mineral ash. It is hard, tough and well suited for the blast furnace. The best and largest coal fields, containing many thousands of millions of tons, are situated about 150 miles from Calcutta, and are connected thereto by more than one line of railway.

Iron ore exists in large quantities in several localities. Of these the three best known are:

1. The Salem District of the Madras Presidency, situated about 113 miles from the sea at Porto Novo, where there is no harbor, and about 199 miles from the port and harbor of Madras. These deposits are inexhaustible, and consist mainly of magnetite and hematite mixed with quartz. The ore is capable of being concentrated by hand-picking to a grade of from 55 to 60 per cent. of iron, 10 to 15 per cent. of silica, and unimportant amounts of sulphur and phosphorus. The small ore and tailings can be concentrated magnetically to 66 per cent. of iron and 3 per cent. of silica.

2. The Chanda District of the Central Provinces contains an inexhaustible supply of fine red hematite of 60 per cent. grade, but unfortunately situated so far inland as to be heavily handicapped. On the completion of certain railways at present projected, the rail distance between the ore and the east coast at Masulipatam will be about 360 miles.

3. *The Iron Ores of Bengal.*—These are widely scattered, and do not, as in the previous cases, occur in enormous masses at a

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given locality. Their grade is from 40 to 50 per cent. of iron, and in many cases the ores are phosphoric. They lie, however, in proximity to the coal fields, and form the source from which the present Bengal Iron Works draws its supply, turning out a pig iron of which the approximate composition is:

	Per cent.
Silica,	2.26
Sulphur,	0.02
Manganese,	2.69
Phosphorus,	1.98

The limestones of India are not at present well explored. It is probable that any large ironworks would draw its supply from the Burmese coast, where quantities exist of a purity of 97 per cent. of carbonate.

In India the government minimum rail freight for goods is one-tenth of a pie per maund (80 pounds) per mile, or 2¾ pies per ton-mile, equivalent to a little under ½d. per ton-mile. There is no doubt that for such traffic as would be necessary for the supply of a large work the minimum rate of carriage for ore and coal could be counted on. In the case of water carriage, the obtainable terms would probably be less satisfactory. The coasting trade is practically the monopoly of a single company, and their vessels are not adapted to the rapid loading and unloading of such cargoes as ore and coal. If any scheme that may be adopted involves coastwise carriage for any of the material, the promoters will do well to provide their own shipping specially designed for the trade.

After due consideration, it would appear that the neighborhood of Calcutta is the most favorable for the site of an iron and steel works. We have here a port open at all times of the year to shipping; the center of a great network of railways, spreading north, south, east and west; the greatest trade center in the East, and a labor market in which the natives have already been trained to the use of machinery, to ironfounding, and, in the case of one establishment, to steel making.

That Calcutta is 800 miles by sea and 200 miles by rail from

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the Salem ore, and 150 miles from the Bengal coal and ore, need not alter the opinion expressed. Most of the readers of this paper are aware that conditions as unfavorable govern the manufacture of hematite iron both in England and in the northeastern States of America. Proximity to the sea is a factor of immense importance in any country, and proximity to a great center of civilization appears to the writer a factor of almost paramount importance in the East.

The conditions, then, which appear to offer the greatest prospects of success are the establishment of a steel works on a large scale, capable of undertaking the whole or a large part of the requirements of India, both as to rails, sections and plates, to be situated either on the Hooghly below Calcutta, or on the Mutlah River at or below Port Canning. This latter site has considerable advantages, which will be enhanced if, as is proposed, it becomes the coal export dépôt for Bengal, to draw the supplies of coal from mines owned by the steel company in Bengal, and the supplies of ore in great part from the magnetite deposits of the Salem district of Madras, and to some extent from the argillaceous ores of Bengal, the supplies of limestone coming by sea from the Burmese coast; all sea transport to be in vessels owned by the company and designed for the trade. Labor-saving machinery, both for winning the minerals, transporting the same, and final manufacture, is essential. A very important item in such a scheme would be the export trade of coal to Madras, and even other ports in the south. It is unquestionable that the profit on such a trade would go far to reduce the cost of importing the Madras ore in the return vessels. Given these conditions, and given that the steel company absorbed the profits from the mining of the minerals to the final out-turn, and carried out the scheme, with a sufficient capital and with honest, unselfish supervision, there is no doubt that remunerative success awaits the enterprise.

It may be calculated that the cost of pig iron manufactured would not exceed Rs. 40 (50s.) per ton, and the cost of finished rails and finished plates are estimated at approximately Rs. 67 and Rs. 85, girders and sections being priced intermediately.

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During the year 1898 the average cost of imported rails was Rs. 81 6a. per ton. The average selling price of angle and tee section steel was not less than Rs. 6 per cwt.

A word may be said on the labor question. It is not pretended that the native of India, as a workman, can compare with a European. His strength is less, and in most cases his intelligence as a mechanic is inferior; but he has advantages which go far to compensate. He is industrious, sober, cheap and not given to the vices of trades unionism. Labor-saving devices which make up for the want of strength and want of skill are desirable, and help to bring the native on a par with the European. It may be noted that all the operations required in manufacturing steel are already in successful operation in India. At the Barakar Iron Works the local ore is regularly made into pig, and for the past six years open-hearth steel has been regularly worked at the government ordnance works in Calcutta, and more recently in the East Indian railway works at Jamalpore. Steel bars and sections of all kinds are rolled in an 18-inch mill in the ordnance works, and machinery and fittings of all kinds are made in increasing quantity at various establishments throughout India.

MESSRS. LOEWE'S MACHINE-TOOL WORKS, BERLIN.

In an article descriptive of these works, recently published in the London "Engineering" particular mention is made of the flooring, as follows:

Administration Building.—We have already in a former notice made reference to the administration building which forms the central block of the premises; this may be said to be the heart of the system, for from it emanates everything that is needed to support the life of the establishment, whilst to it again return the completed work. This department has a 10-ton traveling crane, and the floor is composed of maple planking on pine boards, with a concrete foundation.

The flooring of the whole of the buildings is worthy of special attention. In Fig. 48 annexed we give a sectional view of the

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floor. The arrangement is very well indicated by the illustration. The steel joists are filled in with cement concrete, and there are also imbedded in the latter pine sleepers, to which are nailed 2-inch tongued and grooved pine planks, whilst to these planks are nailed crosswise ⅞-inch hard maple boards 3 inches to 4 inches wide. Messrs. Loewe attach great importance to having a correct description of flooring for machine shops, etc. Maple wood is especially suitable for the upper surface, so much so that the planking in question was brought from the United States. Possibly an equally efficient description of wood could be obtained in Europe, although this is by no means sure, but it was found cheaper to bring the planks, of which there was sufficient to cover six acres, all the way from America, and carry them up from the seaboard to Berlin by barge. The great advantage of maple wood is that it is hard,

Fig. 48. CONSTRUCTION OF MACHINE SHOP FLOORING.

and that it is above everything tough; if chipped it does not splinter, and a heavy machine tool, with a sharp-cornered cast-iron bedplate or feet, can be dragged out with comparative ease, Its cleanliness—especially in the matter of dust—warmth, and the great ease with which it can be repaired, are also highly valuable features.

FILLETS AND ROUND CORNERS ON MODERN MACHINERY CASTINGS.*

Take some machine-tool casting, a lathe, or planer, for instance, made from twenty-five to forty years ago, and compare it with one of the same class brought out at the present time by any up-to-date concern, and what is the first point of contrast noted? You will all answer "the design." Wherein is this difference of de-

* By John M. Richardson. Read at the Pittsburg meeting (May, 1899,) of the Amercan Foundrymen's Association.

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sign? It is to a great extent in the large and smoothly-rounded curves and heavy fillets everywhere present in its outline. Broadly speaking, some of these old-style castings look as though a carpenter had nailed together some sort of a foundation, and then, visiting a planing mill, had procured a quantity of moldings, and with them trimmed it very liberally wherever possible, and finally, by some flourish of the magician's wand this would-be pattern had been suddenly transformed into iron and set down in the machine shop adorned with bright red and green paint, or a combination of both, neither "a thing of beauty" nor "a joy forever." Sharp angles, fancy moldings, panels, etc., look very nice on doors, store counters and a great many kinds of furniture, but are decidedly out of place and likewise impracticable for cast iron.

I consider it of great importance to have a machine casting designed so that its exterior will present as smooth a surface as possible, and all angles and recesses of any kind provided with good, liberal fillets. The advantage of this does not lie along any one line, but everyone of the four mechanical arts, namely, drafting, pattern making, molding and machine work, which are so closely joined and interlocked as to be but four links of a great chain, of untold strength and value to mankind, are each and every one benefitted thereby. A drawing, where this matter has received attention presents a much more finished appearance, and reflects credit on the designer, for it shows that he looked ahead as far as the foundry, realizing that the design and its resultant casting bear a close relationship to one another. Many a condemned casting is such, not through any fault of the molder, but rather from bad proportioning of the metal, sharp angles, no fillets, etc., directly traceable to the drafting room.

In the pattern department fillets serve a very important purpose, and now I am treading on familiar ground, and therefore can, without hesitation, give a short outline of their merits and demerits.

A fillet is actually a pattern strengthener, aside from its foundry value, provided it is composed of a substance having some tenacity in itself, and aside from this property, it is very often a time saver also, for in fitting hubs, bosses and ribs, over curved

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surfaces, or, in fact, any part fitting another, where the intersection does not lie in a plane, much time and labor is required to produce a close fit, but a firm bearing can be quite easily arrived at, having, perhaps, rather open joints here and there, and here the fillet aids the pattern maker by effectually hiding the imperfection. The molder who keeps his eyes open will notice quite a variety of materials worked into fillets on the various patterns he handles, especially if he works in a jobbing foundry. Wood, leather, lead, beeswax and putty comprise the kinds ordinarily used, and they each have their time and place, except the metallic one. A pattern being of wood has a fibrous nature, which will hold glue or any other adhesive substance, while lead has no affinity whatsoever for glue; so the only thing that can be employed is shellac or nails. I have used yards and yards of lead fillets, so can speak from experience, and I have seen old engine beds and their foundation boxes returned for repairs, where these fillets were fairly stripped away from the pattern; even the small bung-head wire nails used would not keep them anchored down.

Probably the finest fillet of all is made of wood, worked out of the solid pattern, having no feather edges whatever, but this is a very expensive kind and can only be used on the finest jobs, so in every-day practice we have to add the fillet to the pattern as a separate part. For fillets from 1 inch radius down to $\frac{1}{8}$ inch, leather is unquestionably the best and most practical material that can be used, and when properly applied will not peel up, even with the hardest usage, and requires no nailing whatever, glue being the only agent employed. Those who condemn the leather fillet for patterns probably do not understand the proper method of applying it. There is a sort of trick about it, to be sure, the keynote of success being hot water. Cover the back of the fillet with thick glue, and place it quickly on the pattern, instantly drawing a round-ended slicking tool of proper radius along its surface, bearing down hard to exude any superfluous glue, and following this with a woolen cloth wet in very hot water, to remove all pressed out by the slicker. Repeat this until not a particle of glue squeezes by the edge of the fillet, then wipe with a dry cloth. This is really not so much of an opera-

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tion as it may seem from the description, and many feet of these fillets can be applied in a very short space of time.

Where it is hard to bind the leather neatly around small curves, etc., just immerse it in hot water, taking it out instantly. This renders it perfectly pliable, but it means quick work, for the thin edges will shrivel and harden at once if not immediately placed in position and burnished down as previously described. A leather fillet put on properly, with strong glue, can only be removed when dry by main force, and will then come off with fibers of the wood adhering to it, and sometimes the leather itself will keep breaking—it takes so much force to make it let go. Light patterns are strengthened by them to such an extent that nails are frequently unnecessary. Beeswax is all right for very small fillets and for finishing out where leather ones come together at the top edge of a rib when the curve is very small, and for many other places. The wax is prepared by being put in a cylinder, having holes of varying diameter in one end. This is warmed and the wax forced through with a plunger, and then applied with a warm slicking tool of the right radius. If used too cold the fillet will not adhere firmly to the wood. In fact, it is hard to lay wax fillets satisfactorily in a cold room, for both pattern and wax are chilled to commence with, and the heated iron bearing on the top surface of the fillet only makes it difficult to communicate the heat evenly enough through the whole mass to secure a firm contact with the wood, and after the pattern has seen constant use in the foundry the wax will peel up badly; also it is not a durable substance for a fillet if sunshine or heat of any kind strikes it to any extent.

Putty has always been used in great quantities in pattern making, and probably always will be, on account of its cheapness. Undoubtedly more feet of fillet can be applied in a given time with this substance for a given amount, taking both the material and labor into consideration, than with anything else; but it is only adapted to cheap work, and not for standard patterns, as it is soft, easily dented, marred or bruised, besides imparting no element of strength whatever to the work. In some places plaster of paris is added to it, to increase its durability, but when

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this is done it must be used immediately after mixing. Black putty is also frequently used. This is nothing but common putty mixed with lampblack, and is employed only on cheap work, having but one coat of shellac, this being applied after the sand papering, thus comparing in color with the blacking on the pattern, and saving a second coat.

When fillets are called for having a radius above one inch, then they must be worked out of wood, and this should be done after gluing to the pattern, not before, in order to have the feather edge adhere as firmly to the work as possible. It is almost impossible not to have the edge curl away if cut out first and then fastened to the pattern, even if the precaution is taken to have the angle of the fillet made slightly greater than that of the corner it fits, in order to cause a binding of the edges.

A mold of any considerable size can be made more safely, quickly and easily and with a minimum of labor, where these points have been considered in the design and carefully followed out in the pattern and with far more chances for perfect casting, as the danger of cracks in shrinking have been eliminated. How many castings are spoiled by having some slender part joined to a heavier one, with no fillet where they come together, thus causing a crack by the shrinkage strain at the junction, it would be hard to determine.

A pattern when heavily rounded wherever possible will certainly leave the sand very much easier and with less danger of breaking the mold, thus saving labor in patching and mending, which is always a form of dead loss to the proprietor on day work, or to the molder on job work, besides being a great vexation to the workman himself.

I would go so far to say that every edge of a pattern, except on surfaces to be machined later, should be rounded, even if the radius of curvature is so small on some light work that it can be done entirely with sandpaper, and on brackets, ribs, heading, etc., it is much more satisfactory when one gets accustomed to it to have the edges terminate in a semi-circular section rather than flat with the two corners somewhat rounded.

This rounding of outside surfaces is necessarily on the pattern

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itself, but there is something else frequently not on the pattern that is expected just as much to be on the casting, and that is the fillets. How many molders can testify to getting patterns with chalk mark all around every corner and rib, and this injunction in two words, "cut fillets," also marked in chalk somewhere on the surface. Once in a great while a case occurs where this is justifiable, but it should be rare. A molder does not profess to be a sculptor, and when he is forced to carve out fillets in the sand who can blame him if, instead of being the radius of a circle they prove to be the hypothenuse of a right-angled triangle. Then, too, there are often places in the mold where it is very difficult to do this, without dropping sand down into parts where it is hard work to remove it, and the result will be an imperfect casting.

Another thing I wish to mention in this connection, although it does not show on the casting except by a fin which must be clipped off before leaving the foundry, is still in the nature of a fillet. When a core is placed in position horizontally, and the cope closed down, the impression made by the core print where it joins the main pattern is liable to be crushed where it enters the body of the mold, unless the molder shaves off the corner so that, at this juncture, the core does not quite touch the edge. This shaving process is done as a foundry precaution, and varies from a slight amount on small work to perhaps $\frac{1}{8}$ inch or more clearance all around where the core enters the mold, this gradually tapering off to the size made by the core print.

The fact of cores coming in the interior of a casting, and the places made by them being entirely out of sight, is a sort of "will-o'-the wisp" to some, who imagine that fillets are unnecessary because they do not show. This is a great error. They are just as much needed here as elsewhere to strengthen the casting, and to help resist shrinkage strains, and should be put in of a size proportioned to the casting to which they belong, but need not be made excessively large, as they frequently are on the outside of a pattern, simply for the graceful effect, for these are not seen. Their place is in the core box, and not as a production of the coremaker's trowel or file. It will sometimes happen that a

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fillet is called for on what is the top, or open end, of a core box, thus making it impracticable for the patternmaker to provide for it. In such cases the coremaker ought not to object to making it in the sand, and, as it comes within the casting, and is out of sight a plain, flat damper is all that is required, and the fillets already in the core box will be a guide for the size. Another case showing the utility of heavily rounded outlines and fillets on castings is when they undergo the cleaning process, and they will also pickle and peel more freely, as there are no sharp corners for the sand to stick into, and thus time and the edges of the cold chisels are saved.

As we reach the machine shop, the man who snags the casting finds no sharp corners full of sand to be scraped out with old files, and as he scours his work down with the coarse emery brick preparatory to painting, he can do much more effective service, for as the stone becomes rounded on the corners with use, it will still clean the large fillets, whereas with sharp corners it could not, and finally, when the iron filler is applied to one of these smoothly outlined castings, it can be sand papered down easily and quickly, so that, after the painting is completed, the effect, when properly done, is almost like velvet.

IMMENSE ELECTRICAL DREDGE.

Increasing interest in the subject of electrical power with reference to its adaptability to vessels of various kinds insures widespread attention to everything having reference to an electrical dredge recently constructed for use on the Volga river, Russia. Distinctly unique, it marks unquestionably a step in advance in the progress of this form of power. The designer is Mr. Lindon W. Bates, an American engineer, who designed the dredge *Beta*, built some time ago for the United States Government, and which has already made a record of 7,800 cubic yards of material per hour. The dredge was constructed by the Societe Cockerill of Belgium, one of the leading shipbuilding establishments on the continent. Trials were held near Antwerp which proved highly gratifying to both designer and builders.

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The Volga dredge is constructed really in two parts, as her beam is limited by the width of the canal system Marie, through which she must pass from the Baltic to reach the Volga. The double dredge can be operated as a whole, making a bottom cut 62 feet wide, or each half can be operated separately. Each half measures 216 feet by 31½ feet wide and 9 feet deep. At light draught the hull draws 4 feet; the working draught is 8 inches greater. The dredge is electrically self-propelling and controllable, the electric installation of each half consisting of a 600-kilowatt generator directly connected to a fore-and-aft triple-expansion engine. The generator supplies two stern motors and two bow motors, each of 125 horsepower, driving 4-foot screw propellers. The generators also supply power to the two 30-horsepower motors mounted in the distributing pontoon and arranged to control the position of the pontoon line as required by operations. Lighting is done from a separate installation. Control of all motors is centralized in the pilot house. Quarters are provided for the crew and Government engineers on each hull. The pipe pontoons are elliptical air jackets, reversible and not easily affected by wind, waves or currents. Metal joints are used, as these do not obstruct the discharge stream so much as rubber connections. Each pair of compound cutter engines works four cutters. Each main-pump engine can develop 1,500 indicated horsepower. The tender is a stern-wheel steamer with a speed of 10 knots an hour. The whole is manifestly much smaller than those used on the Mississippi, more effective, and can take care of more bars or miles of river than any plant heretofore devised.

A Series of Tests.

All parts of the dredge were subjected to searching trials prior to the departure of the plant for St. Petersburg. One set of tests for one-half of the dredge was conducted at Drygoten, Belgium, on a testing ground provided by the Belgian government, in a basin of about 40 acres; the other was conducted at Steendorp, on a bar in the River Scheldt, about 10 miles above Antwerp. Unofficial trial No. 1, at Drygoten, was for the purpose of ascertaining the precision with which a given stratum could be taken,

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and it was found possible by raising and lowering the cutters to take a stratum of thickness up to 7 feet. The dredge advanced at a speed proportioned to the depth of the cut, fast for a shallow excavation, more slowly for a deep one. One test for an average cutting of 2 feet 4 inches resulted as follows: Distance run, 1,200 feet; time, 1 hour and 16 minutes; advance per minute, 15.78 feet; average cut, 2.38 feet; rate per hour, 2,590 cubic yards. The material was of fine, compact sand and clay. This had been formerly farm land below the plane of cultivation. The cultivated surface had been previously removed for the construction of levees. Two weeks later, the first official Russian trial was made in a cut parallel to the former, with higher steam, more pump revolutions, and a crew which had become familiar with the mechanism. In this trial, the result was as follows: Distance run, 1,000 feet; time, 37⅓ minutes; advance per minute, 26.8 feet; average cut, 2.44 feet; rate per hour, 4,524 cubic yards. The material in this cut was favorable, half of it being a loose sand, the other half a compact sand mixed with clay.

Trials of the other half of the dredge were conducted on a large bar at Steendorp composed of very fine sand. Some cuts were along hard, packed material; others were in material relatively loose. None of the material on the Scheldt is of so favorable a character as the coarse, loose sand met with in the cross-over bars of the Volga and Mississippi rivers. Preliminary to the official trials, two prolonged tests were made at Steendorp to determine methods of sounding and measurement. The first test showed an average rate of advance per minute of 10.13 feet; average cut, 5.66 feet; rate per hour, 3,824 cubic yards. In another place, the advance per minute was 9.09 feet; average cut, 4.62 feet; rate per hour, 2,803 cubic yards. It was observed that on account of the hardness of the face, the cutters were not powered sufficiently high to supply the full carrying capacity of the pumps. The second official test, conducted at Steendorp, resulted as follows: Distance run, 2,129.5 feet; time, 3 hours; advance per minute, 11.83 feet; average cut, 3.52 feet; rate per hour, 2,860 cubic yards. Material in this case was fine, compact sand.

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All tests were conducted with 700 feet of discharge pipe. All measurements were in excavation, and, to determine the capacity, upwards of 5,500 soundings were taken. The Mississippi measurements were barge measurements, and to make comparison with the maximum capacity rate achieved by the *Beta*, it is necessary to double the official test No. 1 (4,524 cubic yards) of the half Volga and add 15 per cent., or 10,404 cubic yards, which is 30 per cent. higher than any previous record. At the termination of the trials, it was officially considered that each half of the dredge would be conservatively rated as having an hourly capacity of 2,700 cubic meters, or about 3,500 cubic yards; a total for the whole plant of 7,000 cubic yards per hour. It was also demonstrated that working on a cross-over bar, with a current velocity of 3 to 4 knots per hour, the dredge could be maneuvered with facility with but one line (ahead), thus doing away with half a dozen lines heretofore necessary for holding and maneuvering. As the machine is self-propelling and self-controlling in the current, the electric features have manifestly added enormously to the effective use of the dredge and have minimized all possible interference with commerce.—"Marine Review."

THE OUTLOOK IN THE AMERICAN IRON INDUSTRY.

A rise of 100 per cent. in six months in the price of a commodity so universally used as iron is calculated to startle the world. It requires little sagacity to see that if present values are to be maintained for any length of time, a new basis of all industrial operations is rendered necessary. Will it last? How can it last? Assuming that 1898 prices netted cost to the makers, it would seem to follow that there is 100 per cent. profit in the manufacture to-day. Millions of capital are eagerly seeking investment where one tenth of that return can be assured. Why will not that capital rush in, start the idle furnaces and mills, build new ones, and quickly break down the markets by overproduction? Again, will not new undertakings be checked by the high cost of structural steel, machinery, rolling stock, electrical equipment and the like, so that the great demand will soon

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begin to fall off, and the makers find themselves with more iron than customers?

Questions like these are universally asked by those who produce as well as by those who consume. The answer reaches far into economics—labor conditions, relations with foreign nations, transportation facilities, the physical limitations of mines, waterways, etc., the staying quality of the farmers and laboring masses in their power to buy needed things and pay good prices for them, the rapid increase of gold coinage in the world, and last, but not least, the capricious but powerful factor in all commerce and industry—human nature.

The facts of the rise in prices are fresh in all minds. In the first week in December, 1898, the larger interests in Alabama felt that the better demand warranted adding 25 cents per ton to the price of $7.00, then prevailing for No. 2 foundry pig iron f. o. b. cars Birmingham. It is a somewhat curious fact that, while Alabama produces less than a tenth of the pig iron made in the United States, it is her admitted prerogative to fix prices for the whole market. This is due, doubtless, to two causes. It is the cheapest center of production of raw iron in the world, and its product reaches nearly all consuming markets of the United States, and even of Europe, on more nearly equal terms than that of any other district.

There was not much confidence in the improvement at first. There had been several false starts since the Baring failure in 1890 and the memorable panic of 1893, and nothing was more deeply fixed in the minds of producers and consumers alike than that the era of low prices was here to stay. Here and there a man had a memory and used it. But, for the most part, furnaces and mills sold freely on the first slight advance. When the price was up fifty cents a ton on pig iron and a dollar on steel billets and bars, furnace and mill owners joyfully took heavy contracts. When another dollar was added, along in January, many of the strongest and most conservative concerns in the United States booked their output for three, six, and even nine months ahead. At this writing (September) tens of thousands of tons of material are still going forward on these low-priced contracts. And to

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the honor of the trade be it said that, almost universally, the fulfillment of these low-priced orders is given preference over newer and highly profitable business. Here and there an unscrupulous concern has found the temptation to side track the cheap business too great to resist, but these are rare exceptions to the general rule of good faith and business honesty.

The incredulity of the trade as to the genuineness and extent of the improvement had one conspicuous illustration in the highest quarters. The Lake Superior ore interests are counted the corner-stone of the American iron and steel industry. The owners and agents centering in Cleveland, Pittsburg, Youngstown and Chicago, thought prudence dictated a conservative policy, and opened their books in February at agreed prices, averaging scarcely 25 cents a ton above the very low range of 1898. The ore was snapped up almost in a day, and before the bewildered sellers could tell what had happened, the vast product of all the Lake Superior ranges was sold for deliveries extending to July 1st, 1900. Stockholders of mines and other critics, wise after the facts, have wondered at a policy so very conservative towards the mine owner, and so highly liberal to the furnaces. In the light of subsequent events, it was a huge mistake. But it must be remembered and emphasized that as late as March, only a man here and there in the whole trade showed, by his acts, his faith in the large improvement which was so rapidly to follow.

The following table will show the change that has taken place in prices of a few of the leading products in different markets of the United States:

Pig Iron.	Sept. 6, 1899.	Aug. 23, 1899.	Aug. 2, 1899.	Aug. 31, 1898.
Foundry pig, No. 2, standard, Philadelphia	$22.00	$20.75	$20.25	$10.50
Foundry pig, No. 2, southern Cincinnati	19.25	18.50	18.00	9.50
Foundry pig, No. 2, local, Chicago	21.00	20.50	20.00	11.00
Bessemer pig, Pittsburg	23.25	22.50	21.25	10.00
Gray forge, Pittsburg	19.50	18.50	17.75	9.35
Lake Superior charcoal, Chicago	24.00	23.00	22.00	11.50
Billets, Rails, Etc.				
Steel billets, Pittsburg	37.00	36.00	34.00	16.00
Steel billets, Philadelphia	39.00	38.00	36.00	17.75
Steel billets, Chicago	...	36.80	36.80	17.00

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Billets, Rails, Etc.	Sept. 6, 1899.	Aug. 23, 1899.	Aug. 2, 1899.	Aug. 31, 1898.
Wire rods, Pittsburg	44.00	44.00	43.00	22.00
Steel rails, heavy eastern mill	32.00	32.00	30.00	18.00
Spikes, tidewater	2.35	2.30	2.00	1.40
Splice bars, tidewater	2.05	2.00	1.90	1.05

Without going into a tedious array of statistics, a few leading facts and figures are necessary to an intelligent knowledge of the problems outlined in the first paragraph of this necessarily general sketch. The history of the iron trade in the United States shows a persistent tendency to double consumption and production every decade. When the figures were small, in the years preceding and immediately following the civil war, it seemed no great thing to double in ten years. But when the statistics have grown to huge proportions, leading all the countries of the world, it seems like a geometrical ratio impossible to maintain. But if it is not made in 1900, it will only be because of physical limitations placed on production, not because the demand is wanting. The following figures will help illuminate the subject:

Pig-Iron Production of the United States by Decades.

	Gross Tons.		Gross Tons.
1859	750,559	1880	3,835,191
1860	821,223	1889	7,603,638
1869	1,711,285	1890	9,202,703
1870	1,665,178	1898	11,773,934
1879	2,741,852	1899 (estimated)	13,000,000

Stocks of pig iron in furnace and warrant yards in the United States in 1897 exceeded 1,000,000 tons. September 1, 1899, they had been reduced to about 160,000 tons, as the following figures show:

April 1, 1897,	1,092,113
April 1, 1898,	814,951
April 1, 1899,	302,628
Sept. 1, 1899 (estimated),	160,000

It appears from Mr. Swank's tables that the consumption of pig iron in the United States in 1898 averaged a little over 1,000,000 tons per month. In 1899 consumption is limited closely to the output and may therefore be estimated at 13,000,000 to 13,500,000 gross tons for the year.

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Going back now to the question "Will it last?" Frankly, it must be admitted no man knows. It is not given to mortals to unlock the future. War, famine, pestilence, Bryanism, may intervene and upset all calculations. But the wise man faces the facts as they are before him, and builds his judgment on these, discarding optimism, pessimism, preconceived theories, and even tradition. There were never better settled or apparently sounder commercial traditions in the past than that dollar wheat, ten-cent cotton, and ten-dollar pig iron (at Birmingham) marked the bottom limits in the great staples; but we became familiar with values scarcely more than half these, and men lived and prospered.

The simplest and largest fact in the present situation is a demand greater than the supply. What makes the demand? What limits the supply? The demand is great because seventy millions of people have pinched and economized for six or eight years, and now are quite able to buy, and what is of more consequence are in a mood to buy. They have made the old stove answer, worn out the harvester and threshing machine, postponed the building of the county bridge, got along with the old stationary engine or lathe, put off the purchase of needed rolling stock for the railroad, hesitated to try conclusions with England in the building of ships, and generally have waited for the return of what is known as "good times." Now they want to replenish, from the sad iron to the locomotive. Will they stop because prices advance? No, they will not. Here enters the element of human nature. Confidence breeds confidence. Distrust feeds on itself. Two years ago the great railroads of the United States could have renewed much needed equipment at about half the cost that to-day they do not hesitate to pay. Did they do it? It is notorious that the richest hesitated most. An amusing illustration is the case of a master mechanic of a great road whose requisitions underwent the usual cutting in two in the middle when they reached the management. Among the track and shop supplies needed was a large belt for an engine. When it came it had suffered the usual pruning, and was just half long enough to reach. The writer will not soon forget

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an effort, in the summer of 1897, to find a buyer in New York for 100,000 tons of Alabama pig iron which a large interest was willing to close out at six dollars a gross ton, duly stored in a warrant yard—a price unprecedented in the history of the world. Not one of the great banking houses of capitalists dare face the perils connected with such a proposition, though money was ruling at three per cent., and nearly free storage on the material was guaranteed. To-day almost any bank in New York would lend fifteen dollars a ton on it, and scarcely ask a question.

Buying, therefore, will not stop because prices are up. The railroads must have enormous additions to equipment, or lose the great harvest of profitable traffic. The millions of farmers will buy their agricultural machinery, stoves, carriages and pianos, because crops have been good for three years, fetch good prices, the mortgages are paid off, and there is money in bank. Electrical equipment will not stop while street railways and lighting companies make large earnings, merely because dynamos and rails are dearer. Cities and towns will put in needed water and gas pipe without much regard to whether the cost is $18.00 or $28.00 a ton.

It is perfectly true that some new enterprises, that otherwise would take shape, are deferred because cost is found to exceed engineers' estimates. But this builds a reserve demand that will come in to support the market in the future. In high steel buildings, in large cities, for example, there is a distinct limit to prices that may be paid for materials without bringing the cost to a point beyond earning ability. The merchant marine can not be built up as rapidly from American shipyards on $28.00 steel as on $16.00 steel. But these are but eddies in the main current.

The real factor in lowering prices will be in increased production, not diminished demand. How fast can the output of the furnaces be increased? I say not over fifteen to eighteen per cent. per annum. There was incredulity in as high quarters as Mr. Swank, Secretary of the American Iron and Steel Association, when this prediction was made early in the year. For were there not a couple of hundred idle blast furnaces in the

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country ready to blow in the moment profitable prices were reached? Would American capital or energy hesitate where the reward was so great?

It may be profitable to analyze the factors which operate to restrict profitable production. In a situation like the present they are clearly revealed, and many fine theories are upset by common physical facts. Few people, who have not actually run a blast furnace realize what it means to fill the capacious maw of one of those monsters with raw material. A stack of 200-tons daily capacity, running on 50 per cent. ore, must have delivered to it each day something more than 400 tons of ore, 250 to 300 tons of coke, according to the character of the metal required, and over 100 tons of limestone, besides sand, coal and minor supplies—say 900 tons raw materials. Add the 200 tons of pig-iron product shipped out, and we have a daily freight movement of 1,100 tons, taking no note of the disposition of the slag. This is 55 carloads of 20 tons each. The mining of the ore requires the labor of 150 to 300 men, according to location; the coal mining, coke making, quarrying of limestone and transportation at least 300 more. The furnace itself employs about 150 or more hands. It will be seen, therefore, that starting up a furnace of ordinary capacity calls immediately for the labor, from first to last, of nearly a thousand men; for the use of at least a thousand railway cars and many locomotives; for perhaps several steamers and vessels on the lakes; for capital, from the mines to the pig iron, of one to two millions of dollars, and last, but not least, for a high order of managing ability, the scarcest of all scarce commodities, in times like these.

To use a concrete illustration, the Tonawanda Iron & Steel Co., located near Buffalo, operating two furnaces only, must unload at its docks one good-sized ship load of ore every day during the entire season of lake navigation, or fail to get down its needed supply. Another striking evidence of what it means to bring down the ore for the furnaces now running which depend on Lake Superior mines may be witnessed any day on Detroit River, where the loaded steamers and sailing vessels down, and the light craft up, crowd so close upon each other as almost to touch.

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Still another illustration, at hand as I write, is that of a small charcoal furnace on the lower lakes, needing about 80 tons a day, but unable to start because transportation could not be had for it. To add 1,000,000 tons, or say 10 per cent. to production, means the organizing, equipping, and starting of twenty such operations as described in the preceding paragraph.

The easy theory, therefore, that production can be turned on, as from a faucet, when profits are high, does not fit the facts. It is needless to say that every nerve will be strained to get into operation at the earliest moment the few existing idle plants, but those who base their calculations on an increase of not over 12 to 15 per cent. per annum in the next two or three years, will not go far astray.

It has not escaped notice that in all the present excitement, little is heard of organizing companies to build new plants. Each of the great consolidations is planning additions to capacity, but there are few schemes to develop idle property, as was the case about 1890. There are reasons for this. The building of furnaces to sell town lots was generally disastrous. The impression is still abroad that there is a large reserve idle capacity. But the main factor in restraint is that, under present conditions, it would require at least a year and a-half to build a good modern plant; the cost would be 50 per cent. greater than a year ago—and who knows where iron would be when the furnace was ready to start? The wisdom of the policy of building and enlarging in the bad times, followed for many years by Krupp and Carnegie, is demonstrated in a period like this.

What of the export trade? It is generally believed that this new factor is the all important one in sustaining American markets. Taking the iron and steel manufacture as a whole, I believe this to be true. But so far as ores, pig iron, and even steel billets are concerned, the movements have never reached 5 per cent. of the product of the United States, and probably will not for years to come. Radical changes in the freight and labor situations must occur before America can capture English and European markets with crude iron. She is shipping liberally, it

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is true, and will continue to ship, for prices in Europe will always be regulated pretty closely by those in the United States. But it is in the finished forms where American victories will be won, as they are now being won. In locomotives, wood and iron-working machinery, agricultural machinery, nails, wire, bicyles and a hundred other lines, American inventive genius, great productive capacity, modernized plants, superior business organization, etc., will maintain and doubtless increase the great total of $80,000,000 reached last year in her iron and steel exports. The effect of this great and growing foreign demand is sensibly felt in every department of the trade.

The belief is widespread that exports from the United States must suffer a sharp check, if not come to a full stop, unless prices in America recede. This is a natural, but not well grounded, view. It assumes that the markets of the rest of the world go their way irrespective of what the United States does. That was formerly the case, but it is so no longer. The world is now knit closely together in its industrial and commercial as well as its financial fabric. Influences that affect one nation are soon felt by the others. England and Germany were in the midst of industrial prosperity two years before it was felt in America, but now that she has responded, the added stimulus is felt over there. We think it phenomenal that the mills and furnaces throughout the United States should have their product booked half through next year, but in Germany and Belgium they are already booked all through the year 1900. The great Krupp works at Essen, employing thirty thousand men, are filled with orders until 1901. Germany has nearly overtaken Great Britain in pig-iron product, but is nevertheless importing largely from both England and America to supply her deficiency. Great Britain shows a slackening in her shipbuilding industry, but her export trade in iron is again growing and all her lesser industries are exceedingly active. Prices of iron and steel have risen there almost as rapidly as in the United States. Middlesboro pig that sold last year for 43 shillings has reached 75 shillings and is now a little under 70.

The fact is the great industrial awakening is worldwide. China, India, South Africa, the Philippines, Japan, Russia, and the new

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island possessions nearer to the United States are full of projects for improvement. They have caught the renaissance spirit. The beginnings are small, but they suggest immense future possibilities. They want steam railways, electric lines, electric lighting, water-works, locomotives, machinery, bridges, etc., and it scarcely seems probable that having felt some of the benefits of modern progress, they will decide to turn back. America has shown her ability to compete with the other industrial nations for this trade, and will continue to get it in increasing quantity.

The world's consumption of iron grows in geometrical ratio. In 1740 it did not amount to one pound for each inhabitant. In 1856 it was about 17 pounds per capita. In 1890 it was 35 pounds per capita. In 1900 it will be probably 60 pounds per capita. The following table of consumption in the different countries proves the claim of iron to be the barometer of civilization:

	1856.	1890.
Great Britain, pounds,	144	250
United States, pounds,	117	300
France, pounds,	60	175
Germany, pounds,	50	175
Belgium, pounds,	70	175
Sweden, pounds,	30	100
All the rest, say, pounds,	6	12

In this connection the growth of the world's production of pig iron is interesting. In round numbers, this has been as follows:

In 1856, gross tons,	6,600,000
In 1867, gross tons,	9,300,000
In 1878, gross tons,	14,100,000
In 1889, gross tons,	25,000,000
In 1890, gross tons,	26,500,000
In 1900, gross tons, estimated,	35,000,000

Of the last enormous total there is good reason now to believe that the United States will supply 40 per cent.

A word as to the new level of prices. It is too high, of course, to be permanently maintained. It is too high for the lasting good of this great industry. But we must not be misled by mak-

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ing false comparisons. The conditions reached in the lean years following the panic were abnormal, not natural. Iron was forced to $6 a ton at Birmingham on wages of 90 cents a day for twelve hours' work; on transportation rates that did not return the railroad's cost, and on destruction of royalties or value of the ore and coal in the ground. The same was practically true in the Lake Superior District. It was simply a struggle for life. Values of great properties shrunk from millions to hundreds of thousands. Labor and capital fled to other fields. America learned great and valuable lessons during this trying experience, among others, how to produce iron more cheaply than has ever been done in the history of the world. Perhaps in the end the experience may prove to have been a blessing. But we must not make the error of supposing that those were normal conditions, and that when we have escaped from them we are on an artificial basis. A sound view is that we are nearer normal conditions to-day than we were when 100,000 tons of $6 pig iron went begging for a buyer in New York. A cent a pound for the best pig iron in the world should not, after all, paralyze the faculties of reasonable persons.

It should not be forgotten that the cost of iron resolves itself substantially into three things: labor, transportation and royalties, or the value of the material in the ground. Labor, the largest item, is up 25 to 40 per cent. in iron making. It is not yet too high for the good of the country. Transportation is up about as much, but who shall say the stockholders of the railroads and steamship lines are not entitled to a few dividends after years of waiting? It is now possible to credit ore and coal mines with something for the materials in the ground. But is it a violent assumption that the great iron and coal deposits of the United States, which are usually counted the foundation of wealth in an industrial nation, are actually worth something and should return a profit to their owners on material mined out? If these points are conceded, the legitimate cost of pig iron in the United States is at least 33 per cent. above the low level to which it was forced in the years from 1895 to 1898. The manufacturer's profit, if any, must be added to this. It is some satisfaction to know

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also that cost is rising proportionately in other parts of the world. In great Britain and Germany the increase varies from $2 to $4 per ton, according to kind of metal and locality where it is made. This is due mainly to the steady rise in the price of coke, although ores have advanced and are in short supply.

Cautious investors as well as manufacturers quite naturally look forward to the time when collapse will again take the place of boom, and prices will drop below cost of production. Who shall stand against that day? The strong, who expect to survive, are taking extraordinary measures to equip themselves for whatever may happen. The huge consolidations—at least those newly organized—are free from bonded debts, with large provisions for working capital. Some of them, indeed, are lenders of money in the street. Nearly all have strengthened themselves by ownership of ore mines, coal mines, coke ovens, and even transportation lines, so that they are independent "from the ground up." If the time ever again comes for a fight for existence, it will be between giants indeed, and no other nation can resist American inroads. But every observing man has noted, in the instructive years of the past decade, the wonderful tenacity of life of small plants well located and economically managed. Another thing that has not escaped notice is that in the "survival" struggle, there is a marked tendency to equalize conditions in all the different districts. It is a fact capable of demonstration that the best returns on capital during the lean years were not from the great concerns in the most favored locations (barring one or two exceptions), but from certain smaller operations located in districts not usually spoken of as the cheap centers of production. It is a safe assumption, therefore, that, whatever lengths the consolidation movement may extend to, there will be plenty of strong undertakings on the outside that will keep the industry on the sound footing of free competition.—Archer Brown, in "The Engineering Magazine."

"THE AGE OF NICKEL-STEEL."

During the year 1890 Hon. Benjamin F. Tracy, then Secretary of the United States Navy, received, in confidence, the informa-

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tion that Schneider & Co., of Le Creusot, France, had invented a new armor plate which contained about 3½ per cent. nickel. With characteristic American eagerness to procure the very best armor for the protection of its warships, and with the view of making a thorough test of the best plate produced in other countries, an order was placed in Europe for three plates, one from England and two from France. The one from England was of the same character and composition as was then specified by the Admiralty for warships. One of those ordered from France was of plain steel and one was nickel-steel. These three plates were in due time set up side by side at the Annapolis testing grounds and fired at by a 6⅛ inch gun at a distance of 50 feet. The British plate was broken in pieces, the French plate was badly cracked, while the nickel-steel plate suffered comparatively little injury.

This test proved very conclusively that the nickel-steel plate was what the United States Government desired for the protection of its warships. In fact, it was not only a revelation to the civilized nations of the earth, but caused a complete revolution in the manufacture of armor plate. Congress immediately voted $1,000,000 for the purchase of nickel, and the Department changed all its contracts for armor plate and specified nickel-steel plates. Thus it was that in the year 1890 we entered upon the "age of nickel-steel," through the initiative of a citizen of France. Its development was due to America's combining with it the Harvey process for face hardening nickel-steel armor plate.

The nickel-steel of commerce as used for the production of armor plate, driving and piston rods, tires, axles, propeller shafts, &c., is made by the open-hearth process, and generally contains 3 to 3½ per cent. of nickel. The introduction of this small amount of nickel in steel gives us an increase in elastic limit of 75 per cent. and in tensile strength an increase of 30 per cent. over simple steel, without any impairment of the elongation or the reduction of area. A defect in a nickel-steel forging will not develop, and does not necessarily mean that the forging will fracture at that point, as would undoubtedly be the case in simple steel.

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These facts then further demonstrate to us that in the production of nickel-steel for various commercial purposes we have a thoroughly reliable metal which is absolutely free from the treacherous brittleness due to crystallization so characteristic in simple steel.

When pure commercial nickel some years ago was selling around $7 per pound we were compelled to admit that the field did not look very inviting for manufacturers to experiment. At the present time, however, with nickel selling between 30 and 40 cents per pound, the production of nickel-steel is growing to enormous proportions, owing to its many virtues, which the modern manufacturer is compelled to recognize. While the first cost is somewhat more than that of simple steel, the additional extra cost of 3 or 3½ per cent. nickel at say 40 cents per pound is very insignificant, when it is considered that nickel-steel will outlast simple steel several times in the general wear and tear.

In the production of nickel-steel by the crucible process numerous interesting and valuable results have been obtained. It has been my experience that for every per cent. increase in nickel contents there is a corresponding increase in the hardness of the metal, and a decrease in its ability to take a temper, until we reach 16 to 18 per cent. nickel. At this point the metal becomes exceedingly hard and extremely difficult to machine, but it can be worked, when heated, into almost any desired form by rolling, or forging, in the ordinary manner as practiced in manipulating simple steel. By continuing to increase the nickel contents beyond the point mentioned the material becomes softer, and at 25 per cent. nickel we have an exceedingly soft, ductile alloy which cannot be hardened in water, but is capable of being pressed, bent, rolled or drawn cold into various forms for bicycle spokes and parts, spoons, saddlery, hardware, etc.

At the extreme hardness of 16 to 18 per cent. nickel extraordinary fine table knives may be produced, by simply forging to shape and continuing with light hammer blows until the heat disappears from the blade. After the knives become cold it will be found that the blades are very elastic, free from the danger of breaking when bent, like simple steel blades hardened and tem-

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pered in the usual manner. The knives when polished assume a most beautiful luster, tinged with a delicate blue so prized by the steel maker.

Crucible steel not containing over 5 per cent. nickel in combination with various percentages of carbon makes an extremely tough, tenacious product, suitable for edge tools, springs, &c. Experiments, however, in this direction have led me to prefer a nickel content of from 2½ to 4½ per cent., as I find a very marked decrease in the ability of the product to take a satisfactory temper beyond the 4½ per cent. limit. When kept within the limits mentioned, and when proper care is exercised in its manufacture, the product is an ideal tool steel of wonderful endurance, capable of great execution after forging to shape and hardening and tempering in the usual manner.

Since nickel-steel chills rapidly it is necessary that the crucibles be removed from the melting fires at a good, clear heat and that casting be done immediately. It would be well to bear in mind that, owing to the great affinity existing between nickel and oxygen, a suitable flux must be used in order to eliminate the latter and to prevent the nickel from oxidizing during process of fusion. Otherwise the product will be a mass of spongy, seamy material unfit for commercial purposes.

The addition of nickel to simple steel appears to admit of a higher degree of heat in forging, rolling, &c., without danger of segregation. A very good demonstration of this fact can be had by introducing a few ounces of nickel to a mixture of air or self-hardening steel, when it will be found that the material may be forged at a somewhat higher heat than is customary, and that the product now combines toughness with hardness, which is absolutely essential in the production of a first-class self-hardening steel.

Extraordinarily fine watch main springs, 0.008-inch in diameter and 0.115-inch in width, containing 3 per cent. nickel with carbon about 1 per cent., have been produced that could be wound and rewound upon a small mandrel in opposite directions a number of times without any impairment to the springs, and surpassing in elasticity the best cast simple steel. Excel-

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lent nickel-steel pens, that glide over the paper when writing as though they were lubricated, have been made from steel with a nickel content of 4 per cent., and as the consumption of cold-rolled simple steel for pen points is nearly 1,000 tons per year a valuable market awaits the former product on account of its superiority over simple steel. Cold-drawn wire containing from 20 to 30 per cent. of nickel made into bicycle spokes shows a wonderful degree of toughness, combined with the ability to swage and thread perfectly. Wire of this description has a tensile strength of about 190,000 pounds, and an elastic limit of about 130,000 pounds, and may be tied into a knot cold without fracture.—H. J. Williams, in "Iron Age."

THE WIRELESS-TELEGRAPH TESTS IN THE U. S. NAVY.

The "Electrical World and Engineer" of November 11th notices recent experiments of this system in the following paragraph:

The practical tests of the Marconi system of wireless telegraphy, which have been conducted during the past two weeks on United States warships, and which tests were referred to in these columns last week, were concluded on November 1. At the Highlands of the Navesink a station was established, and placed in charge of Lieutenant Blish, for the purpose of interrupting messages sent between the *New York* and *Massachusetts*. The interference apparatus on the Highlands consisted of a 150-foot vertical wire triced up on a pole. To the foot of this wire a Marconi instrument was attached, so that when a message was sent from the Navesink station it would interrupt any messages being sent at the same time within the radial circumferences of the electrical wave produced by the sending of the message. The two warships left their anchorage off West Thirty-fifth street on Monday forenoon and went down the bay, where the tests were begun. On the way messages were exchanged successfully and to the expressed satisfaction of the commission. When the warships arrived off Navesink the *New York* anchored and the *Massachusetts* steamed out to sea thirty-six miles, for

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the purpose of making long-distance tests, and also to try the extent of the interference the apparatus at Navesink would exercise while messages were being exchanged between the warships. All the time the *Massachusetts* was making her way to sea messages were exchanged between her and the *New York* at intervals of ten minutes, and interference messages were sent by the operator at Navesink at longer intervals. The interference messages were successful, and rendered the messages between the warships unintelligible. At a distance of thirty-six miles the messages sent by the *New York* to the *Massachusetts* failed to carry, and the battleship came back and anchored a few hundred yards from the *New York*. During the day forty-five messages were sent by the *New York*. Of these twenty-three were received and five were interrupted. The storm that came up on Monday night disabled the wireless-telegraphy apparatus, and on Tuesday afternoon the *New York* and *Massachusetts* were compelled by the rough weather to come inside Sandy Hook. While going out to sea Wednesday morning a man fell overboard from the *Massachusetts*, and the news was telegraphed wirelessly to the *New York* ten minutes before it could be wigwagged by the signal man. The man was rescued by a cutter. The tests were continued all day and were pronounced satisfactory. Before beginning the experiments Mr. Marconi wrote to the commission, explaining that he had not received sufficient notice to enable him to get his instruments in shape. He added that he had an instrument which would render interference practically impossible.

We append to the above the following from the "Army and Navy Register:"

The conclusions and recommendations of the Naval Board on the experiments with wireless telegraphy are as follows:

1. It is well adapted for use in squadron signalling under conditions of rain, fog, darkness and motion of ship. The rain, fog and other conditions of weather do not affect the transmission through space, but dampness may reduce the range, rapidity and accuracy by impairing the insulation of the ærial wire and the instruments. Darkness has no effect. We have no data as to

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the effects of rolling and pitching, but excessive vibration at high speed apparently produced no bad effect on the instruments, and we believe the working of the system will be very little affected by the motion of the ship.

2. The accuracy is good within the working ranges. Cipher and important signals may be repeated back to the sending station if necessary to insure absolute accuracy.

3. When ships are so close together (less than 400 yards) adjustments (easily made) of the instruments are necessary.

4. The greatest distance that messages were exchanged with the station at Navesink was 16.5 miles. This distance was exceeded considerably during the yacht races when a more efficient set of instruments was installed there.

5. The best location of instruments would be below, well protected, in easy communication with the commanding officer.

6. The spark of the sending coil or of a considerable leak due to faulty insulation of the sending wire would be sufficient to ignite an inflammable mixture of gas or other easily lighted matter, but with the direct lead (through air space if possible) and the high insulation necessary for good work, no danger of fire need be apprehended.

7. When two transmitters are sending at the same time, all the receiving wires within range receive the impulses from transmitters, and the tapes, although unreadable, show unmistakably that such double sending is taking place.

8. In every case, under a great number of varied conditions, the attempted interference was complete. Mr. Marconi, although he stated to the board before these attempts were made that he could prevent interference, never explained how nor made any attempt to demonstrate that it could be done.

9. Range of signalling: Between large ships (heights of masts 130 and 140 feet above the quarter deck) the range is at least 35 sea miles at sea and 16.5 miles or less when tall buildings of steel frames interfere. Between a large ship (height of mast 140 feet) and a torpedo boat (height of mast 45 feet) across open water, signals can be read up to 7 miles on the torpedo boat and 8.5

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miles on the ship. Communication might be interrupted altogether when tall buildings of iron framing intervene.

10. The rapidity is not greater than 12 words per minute for skilled operators.

11. The shock from the sending coil of wire may be quite severe, and even dangerous to a person with a weak heart. No fatal accidents have been recorded.

12. The liability to accident from lightning has not been ascertained.

13. The sending apparatus and wire would injuriously affect the compass if placed near it. The exact distance is not known and should be determined by experiment.

14. The system is adapted for use on all vessels of the Navy, including torpedo boats and small vessels as patrol scouts and despatch boats, but it is impracticable in a small boat.

15. For landing parties the only feasible method of use would be to erect a pole on shore and then communicate with the ship.

16. The system could be adapted to the telegraphic determination of differences of longitude in surveying.

The board respectfully recommends that the system be given a trial in the Navy. Respectfully,

J. T. NEWTON, Lieutenant Commander, U. S. Navy.
J. B. BLISH, Lieutenant, U. S. Navy.
F. K. HILL, Lieutenant, U. S. Navy.

To the Chief of the Bureau of Equipment.

NEW GERMAN DRY DOCK.

The new Kaiser Dry Dock in the Kaiserhafen at Bremerhaven is the first German dry dock entirely built of stone, the largest in Germany, and one of the largest in the world. It has an effective length of over 722 feet, a middle breadth of 90½ feet, and an effective depth of 31 feet. The sill of the dry dock is 7 meters below Bremerhaven zero, and 1,056 meters below the ordinary high water of Weser. The new dry dock, with its entrance basin is situated in the north corner of the Kaiserhafen, and there is a wet dock of 200 meters length, in which ships can be repaired

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when floating, and further space for another dry dock of the same dimensions as that already constructed. A turn bridge, over which several lines of rails are conducted, connects the two sides of the entrance to the basin. The closing of the dry dock is done by a lifting pontoon, which can be removed from the outer end of the dry dock 60 meters inside the dry dock in order to save time and expense when vessels of smaller size are docked. A steam water engine is used for emptying the dock, which can be effected in from two to two and a-half hours, whereby 75,000 cubic meters of water are raised. On each side of the dry dock two cranes of 50 tons capacity are erected, and in the southeast corner of the wet dock a crane of 150 tons lifting capacity is constructed. All these cranes, as well as the lighting of the whole dock, is done by electricity. The North German Lloyd has taken the new dry dock in lease for twenty-five years, and under the condition that the Imperial German navy can also always use it.—"Engineers' Gazette."

TESTS OF BRITISH GAS ENGINES.

At the Edinburg show of the Highland and Agricultural Society of Scotland, which took place during July, a number of gas engines were exhibited and a committee appointed to test their relative efficiency. The power developed by each engine was obtained by the Prony brake and by the indicator, and the amount of oil fed to each engine was measured. The engines were required to run for four hours on the first day at full declared brake load. This was followed on the second day by a two-hours' run at half load, afterward by an hour's light-load trial; finally each engine was run for a short time at its maximum load. This last trial was made in order to ascertain the maximum power that could be developed on an emergency. The Crossley, Stephenson, Pollock and Cundall engines were supplied with "Royal Daylight" oil of 0.796 specific gravity, and the other engines with "Russolene" oil of a 0.825 specific gravity. The results of the test are shown in the accompanying table, which is taken from "The Engineer":

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SUMMARY OF TRIALS OF OIL ENGINES.

.....	Crossley Bros., Limited.	Campbell Gas Engine Co.	R. Stephenson & Co.	Blackstone & Co.	Tangyes, Limited.	R. Cundall & Son.
Diameter of cylinder, ins..	10	12½	7	9½	11	8¾
Stroke, inches.....	18	21	12	18	16	15
Full-power trial:						
Revs. per min., mean...	204	188	252	190.3	200.1	227.7
Mean effective pressure, lbs. per sq. in...	64.52	49.5	5.39	56	62.2	...
Explosions per minute, mean.....	87.25	76	118.5	81.4	89.75	...
Indicated horsepower..	20.09	24.48	5.39	14.68	21.43	...
Mechanical efficiency..	.771	.773	.582	.858	.842	...
Brake horsepower.....	15.5	18.93	3.14	12.6	18.06	8.77
Oil pr. B.H.P. pr. hour, pounds.....	.793	1.20	1.63	.746	.806	.962
Half-power trial:						
Brake horsepower.....	7.71	10.59	1.31	6.59	9.95	4.35
Oil pr. B.H.P. pr. hour, pounds.....	1.037	1.466	2.88	1.024	.930	1.57
Light trial:						
Total oil per hour, lbs..	4.03	8.23	4.43	3.4	3.375	4.24
Maximum-power trial:						
Brake horsepower.....	18.01	25.55	3.14	19.7	29.66	10.54

SHIPBUILDING IN DENMARK.

The Elsinore Ship and Machine Building Company has, during the last financial year, had a turnover of 3,271,000 kroner (£180,000), against 2,831,000 kroner the previous year. In wages it paid 1,030,000 kroner (£57,000), and 976 hands were employed. Including apprentices, the average wages have been 1,055 kroner (£58 12s. 3d.). By negotiations with the trade union an increase of the wages has been decided upon. The profits on the year amounted to 682,674 kroner (£38,000), 100,461 kroner have been written off, and 90,000 kroner added to the reserve fund. The shareholders receive a dividend of 6 per cent. There have been 121 ships on the company's slips, and 173 have been repaired; seven new steamers, with an aggregate of 7,710 tons, have been delivered. An extraordinary meeting of the shareholders of

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the Danish Machine Manufacturing and Shipbuilding Company, which was formed earlier in the year, and acquired valuable sites and water power at the Strandmöller, has decided to purchase the concern known as the Stellerup Shipyard. A debenture loan of 300,000 kroner in this latter concern will remain unaltered, and each share of 2,000 kroner in the Stellerup Shipyard is exchanged for a 1,000 kroner share in the new company, and 15 per cent. is paid in cash. The share capital of the Danish Machine Manufacturing and Shipbuilding Company (Dansk Maskinfabrik og Skibsbyggeri) will be increased by 300,000 kroner. The Burmeister Shipbuilding and Engineering Company is at present very busy; a large order has now been finally secured from the Russian company, and great activity prevails both in the shipyard and in the engineering departments, which are being materially extended and where a number of large and entirely up-to-date machine tools have been installed. Electric motors have been adopted on a large scale.

CENTER OF GRAVITY OF LOCOMOTIVES.—SIMPLE METHOD OF DETERMINING.

The determination of the center of gravity of locomotives is a laborious task when computed mathematically, because in order to be accurate the weight and location of the center of gravity of each and every piece should be ascertained and their moments above the rail figured out, but the labor being so great, assumptions are made which affect more or less the final figures. It occurred to the writer that a practical method could be applied and the following was therefore evolved:

Suppose that we have a body of symmetrical cross section, the weight of which is known. If this body be tipped slightly so that one of the edges upon which it stands is lower than the other, the center of gravity will be displaced laterally. If this body rests upon supports at the two lower edges only, then the lower support will sustain more weight than the higher one, due to the lateral displacement of the center of gravity, and if the angle is such that the center of gravity be vertically over the lower edge, the total weight will come on this edge, and the

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body will be in unstable equilibrium. Thus, in Fig. 1, the whole weight will come upon the support *B*, but in Fig. 2 a portion will rest upon *A* and another portion upon *B*, but the sum of these two will be equal to the total weight. Let the weight of a symmetrical body be represented by *W*, the load on each sup-

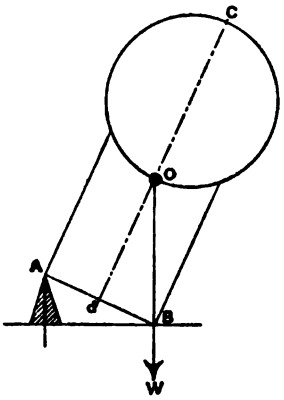

Fig. 1.

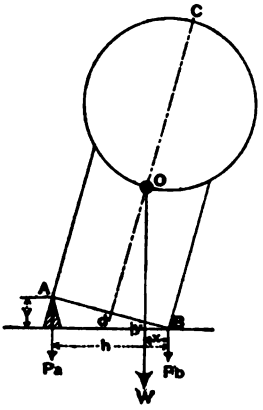

Fig. 2.

port by *Pa* and *Pb*, respectively; then *Pa* plus *Pb* equals *W*. Let also the horizontal distance between the supports be represented by *h* and the vertical difference by *v*; also the distance measured horizontally between the support, *B*, and a vertical dropped through the center of gravity be represented by *x*. Now, by equal moments $Pa \times h$ equals *WX*, and *X* equals

$$\frac{Pa\ h}{W}.$$

As the body is symmetrical, the center of gravity must be in the central axis *c-d* and at the intersection with the vertical through *y*, at a distance *X* from *B*, or at *O*. This may be laid off graphically or it may be calculated by similar triangles.

The reproduced photograph, Fig. 3, illustrates the application of this principle to locomotives. The engine was first carefully weighed on the track scales, with a certain height of water, etc., and was backed off the scales. The rail was then removed from the narrow side of the scale platform, and blocks laid close to-

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gether, like ties, from the outer frame to the fixed or dead rail support, care being taken to see that the portion of the scale under these blocks was entirely free. A rail was laid to gage on these blocks, and a slope prepared at one end. All was now ready, and the beam being balanced, the water was brought to the same level as before in the boiler, and the engine run upon the new track, and the load upon the lower rail weighed. While the engine is upon the scales, a level should be run from rail to rail to determine the exact difference of level for use in making the calculations; in the case illustrated this was about 7½ inches. Of course, there is a slight error, due to shifting of the water sidewise in the boiler, which tends to exaggerate the result. The frames should be blocked over the boxes, so that the boiler will stand relatively to the wheels the same as on level track.

If care be taken, accurate results may be obtained, as, with the small elevation mentioned, an increase in weight of 25,000 pounds on the lower side of the engine was shown by the scales, the total weight of the locomotive being about 140,000 pounds.—G. W. Henderson, in the "American Engineer and Railroad Journal."

REPAIRING VESSELS AT CAVITÉ.

Naval constructor Hobson has some pertinent comment to make on the question of dry-docking facilities required by the Government at Cavité, which he embodies in a report submitted to the Navy Department recently, on the question of the wrecked vessels raised in Manila Bay, which are now being repaired at Hong-Kong under his direction. Mr. Hobson contends that economy demands that the United States establish its own dock and repair station, and shows that large sums would be saved which are now paid private firms at Hong-Kong for overhauling American warships.

His report is an argument in favor of the maintenance in the Philippines of an important navy yard and dry dock, where the largest and most powerful vessels of war may be overhauled and attended to. The report states that in compliance with the bureau's direction the three vessels under reconstruction, the *Isla de Cuba*,

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Isla de Luzon and *Don Juan de Austrias*, are about 80 per cent. completed. The value of the vessels when completed, exclusive of armament, will be about as follows: *Isla de Cuba*, $215,000; *Isla de Luzon*, $215,000; *Don Juan de Austrias*, $180,000. Total $610,000. Raising and refitting have cost about $304,000, making a net gain to the Government on the three vessels of $306,000. The credit for this result is given to Naval Constructor Capps, who made the contracts. Thus the large engine parts were scarcely injured at all. This feature has an important bearing upon the wrecks still in Manila Bay, which he is to examine with divers when the vessels now in hand are completed. The longer period that they have been immersed may not have seriously injured the principal parts, and there may be similar advantage to the Government in further salvage, particularly as to the *Don Antonio de Ulloa* and the *Velasco*, sister ships to the *Don Juan de Austrias*, which, from all accounts, suffered less damage than those that have been raised.

Mr. Hobson adds: "There would be great advantage to the Government in the establishment in the Philippines of a yard thoroughly equipped with docks and plant capable of doing all the work of docking and repairing of the navy. The British Government is undertaking such an establishment here, though at great cost, involving the making and reclaiming of a large part of the land required. This would necessitate the employment of Chinese labor. This labor is not only unlimited, but it is equal to practically all the requirements of modern industry. Chinese do all the work inside and out for all the departments of the shipyard, white supervision being required only to show what is wanted. The Chinese have a remarkable natural aptitude. Their industrial capacity is simply marvelous. To the extent of my observations and inquiries, there is no place in modern industry which they can not fill."—"Scientific American."

THE COST OF CHEAP MEN.

Capitalists have been acquiring a little education of late in the matter of the considerations to be taken into account in

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dealing with workmen. Some of them have believed that nothing needed to be regarded except wages. If you could save 25 cents a day on the pay of each man you hired, you would be just that much ahead. But there have been some incidents recently that have tended to upset this apparently reasonable theory.

For instance, after the Brooklyn Rapid Transit Company had got rid of most of its experienced men and put strangers in their places, it began to suffer from accidents, delays and complaints of patrons. It also found its receipts diminishing, and one of its officials alleged that some of the new conductors were "knocking down" 90 per cent. of the fares.

The other day the *Campania* came into port at New York with Lord Charles Beresford and a lot of other disappointed passengers, just too late to see the Dewey celebration. She had been delayed by a set of green firemen, taken on because the old hands were on strike. The extra coal alone consumed on the voyage would probably have more than covered all the demands of the strikers.

Last week the British merchant marine was disgraced by a repetition of the *Bourgogne* horror under the British flag. The steamer *Scotsman* was wrecked in the Straits of Belle Isle and a number of women perished through the ruffianism of the cowardly crew. When some of the men were arrested at Montreal they were found to be loaded with dresses, silk stockings, underwear, watches, jewelry, cameras, diamond rings, pins, rings, brooches, purses and sealskins, which they had stolen from the dying passengers. These men, we are told, were "green hands, who had been shipped on account of the strike in England of sailors and firemen."

Cheap men in these cases seem to have come rather high.—"Philadelphia North American."

RELATIVE CORROSION OF VARIOUS METALS.

The following results were obtained for the National Tube Co. and the Oxford Copper Co. by Henry M. Howe, October 17,

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1899, in the loss of weight of wrought iron, soft steel and nickel-steel in pounds per square foot of surface per annum, when exposed to—

	Sea-water average.	Fresh-water average.	General average.
Wrought iron,	.1409	.1275	.10386
Soft steel,	.1612	.1204	.10906
Low nickel-steel,	.1173	.1021	.08299
High nickel-steel,	.04518	.04404	.03416
General average,	.11615	.09851	.08252

STABILITY OF THE *NEW ORLEANS* AND THE *ALBANY*.

In our issue of July 1, we commented at some length upon the sensational rumors regarding the instability of the *New Orleans*, which, emanating from the Washington press, were taken up and elaborated by the press of Philadelphia and other shipbuilding centers. As we pointed out at the time, inquiry at the Brooklyn navy yard, where the inclining experiments on the *New Orleans* were made, showed that these statements were based upon a misconception or a misunderstanding of the report of the inclining tests.

In the determination of her stability in light condition, the vessel was considered stripped of all consumable weights and was placed in the most unfavorable condition possible. She was entirely emptied of coal, water and stores, the coal representing a lightening of 800 tons and the water of 220 tons. Not only were the boilers and tanks emptied of water, but all water was removed from the double bottom. The ammunition, representing 120 tons, was also removed, and neither the crew nor their supplies were on board. Indeed, the ship was put into a condition which, if she were upon the high seas, would constitute her a derelict.

When this process of stripping was completed, a certain number of cast-iron blocks of known weight were shifted across the deck, and from the angles of inclination of the ship so obtained the metacentric height, or stability, was calculated. The results

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showed that when the *New Orleans* is absolutely empty, she has a negative metacentric height of 0.48 foot, or about 5¾ inches; which means in lay phraseology that she would not, in this condition, float upon an even keel, but would take a slight list until, by immersing a fuller waterline, she found sufficient bearings. Now there is in this nothing unusual. It occurs whenever an ocean liner is absolutely empty, and provision is made in all merchant steamers, as in the *New Orleans*, for correcting the list by introducing water ballast into the double bottom of the vessel. The inclining experiments showed that when the *New Orleans* is fully equipped for sea, with all coal, ammunition, and stores on board, she has a positive metacentric height of 1.7 feet. Advantage was taken of the recent visit of the *New Orleans* to dry dock, preparatory to her voyage to the Philippines, to subject her again to a series of inclining tests, which showed practically the same results as those of last June.

In the report which was made to the Bureau of Construction and Repair, at Washington, it was suggested that whenever the ship at sea was approaching the light condition, because of depletion of her bunkers, ammunition or stores, it would be advisable to introduce a certain amount of water into her bottom tanks. There is nothing new in this suggestion; it has been made before with regard to other ships of our navy, and as a matter of fact the *Philadelphia*, which has considerably less metacentric height than the *New Orleans*, has to keep water in her double bottom to give her the desired stability.

Unfortunately, in transmitting the report of these tests of the *New Orleans* to the Secretary of the Navy, the bureau at Washington made the following comment: "This at once marks her as a *dangerous vessel*, requiring great care, when in service, on the part of the commanding officer." It is a matter of great regret, both upon the part of the officers who have commanded this fine vessel at sea and the officers of the construction corps, that such an unfortunate misconstruction should have been put upon the results of the inclining experiments. These gentlemen do not consider the *New Orleans* to be "dangerous;" ridicule the suggestion that she is untrustworthy; and they regret that

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any such impression should have been gathered from what was an ordinary routine inclining test, such as is carried out upon every new vessel of the United States Navy.

In this connection it may be mentioned that tests of the *Albany*, sister ship to the *New Orleans*, which have been made at the Armstrong works, where the *Albany* is completing, show that in the empty condition she has a positive metacentric height of 1.22 feet, and a metacentric height, when fully loaded, of 2.69 feet. The difference in the results as found in the two vessels may be accounted for by the fact that the *Albany* was short of her full weight by an estimated amount of 321 tons, and that other estimated weights had to be taken out; a slight error in these calculated weights, or the presence of bilge water in either ship, might affect the results sufficiently to account for the difference.

In any case, it is reassuring to know that in respect of her seaworthiness the *New Orleans* is indorsed both by naval constructors and by the line officers who have sailed her in every kind of weather. The captain of a ship is always particularly alive to anything in the motions of his vessel in a seaway that betokens a lack of stability. He has a quickness of perception, born of long experience, which would detect this unpardonable fault at the first indication of its existence; yet we are assured by those who have had charge of her that even in the light condition she has shown ample evidence of stability.—"Scientific American."

ANNUAL MEETING OF THE SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS.

The "Engineering News" of November 23, gives a very excellent "brief" of the proceedings, which we reprint practically in full.

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The seventh general meeting of the society was held at the house of the American Society of Mechanical Engineers in New York city on November 16 and 17. In most respects the meeting was a very successful one. There were fourteen papers on

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the programme, and the majority of them received discussion. Considerable time was wasted, particularly at the first day's session, by the authors of the papers reading them in full. This practice is, however, a common mistake of convention work, and the naval architects are no worse in this feature than many of their sister engineering societies. Where the papers are printed and distributed well in advance of the meeting, reading them by abstract, or, in some instances, by title only, will usually promote rather than restrict discussion, and will save a great strain upon the patience and good temper of the majority of the members who have already studied the paper. This fact was evidenced in the work of the second day's session, when most of the papers were read in abstract, and when the discussion, instead of being curtailed thereby, was, if anything, more active than during the first day's meeting.

The opening sessions of the meeting were presided over by Rear Admiral Francis M. Bunce, U. S. Navy (retired), the president of the society, Mr. Clement A. Griscom, being absent on a trip abroad. Mr. Griscom's presidential address was read by the secretary, and was in part as follows:

Whatever may be the political, moral or constitutional aspects of a policy of expansion, it is not without advantages to shipbuilders. The large number of vessels purchased by the Government last year for use of the Army and Navy, together with increasing use of steam vessels in the coasting trade, have produced the greatest activity ever seen in our coast shipyards, both on the Atlantic and the Pacific oceans. The orders for large steel steam vessels now taken exceed largely those of any year in our history. The record on the Great Lakes is such as to tax the capacity of the shipyards of that district until the fall of 1900. There are now building or to be built on the lakes, 26 steel vessels of large size of an aggregate value of about $8,000,000, and an aggregate carrying capacity of 154,000 gross tons. These vessels comprise one passenger vessel, two steel barges of 7,000 tons capacity each, five steamers of 3,000 tons capacity, suited to trade between the Great Lakes and the Atlantic seaboard, and eighteen steam freight vessels of about 6,000 tons capacity.

On the sea coasts we have the unusual condition of nine steamships building for ocean commerce. At least nine large steam-

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ers, recently built, have been added to the coasting or West Indian trade in the past year.

This is probably the first occasion that I have found any statistics in regard to American shipping industries of a character desirable to contemplate, and even now I feel obliged to accompany them with a note of warning, "One swallow maketh not a summer." The proportion of our export and import trade now carried in American bottoms is too small to be mentioned, and last year was smaller than ever before. To make this percentage a respectable one would require ten times the number of American shipyards working at full time for a number of years. While we have the materials, the tools and mechanics, the successful building of a modern vessel from a commercial point is in reality a triumph of organization of the multitude of diversified trades which it includes. This stage is yet to be reached, and can only be attained by regular systematic production. Production depends upon a market and upon traders who see a profit to be made in shipowning under the laws of the United States.

The secretary's report showed the total membership to be 573, not including the members elected during the meeting. The total receipts during the year from all sources were $5,614, and the total expenditures were $5,669. The balance in the treasury was $3,586, and the total resources of the society were $13,935, with no liabilities.

The first paper on the programme was presented by Mr. Spencer Miller, M. Am. Soc. C. E., and was illustrated by lantern slides and models.

Coaling Vessels at Sea.

The paper described briefly the various devices proposed in the past for coaling vessels at sea, and concluded with illustrations and a description of the cableway system devised by the author and soon to be tested with the U. S. S. *Massachusetts* and the collier *Marcellus*. This system was described in its general features as follows:

(1) It is proposed, with this device, for the warship to take the collier in tow, or the collier to tow the warship, leaving the distance between ships about 300 feet. This method of securing boats at sea is recognized as being safe.

(2) The warship to receive the coal will erect a pair of sheer

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poles on its deck, which, secured by guys, will support a sheave wheel and a chute to receive the load.

(3) The collier is provided with a specially-contrived engine located aft the foremast, having two winding drums. A steel cable, ¾-inch diameter, leads from one drum to the top of the foremast, over a sheave, thence to the sheave on the warship, back to another sheave on the top of the foremast, thence to the other drum. This engine gives a reciprocating motion to the conveying rope, paying out one part under tension; a carriage secured to one of the parts passes to and from the warship, its load clearing the water intervening.

(4) A carriage of special form is provided with wheels which roll on the lower part to the conveying cable, and grip slightly but sufficiently the upper part of the cable. This carriage will carry bags of coal weighing 700 to 1,000 pounds. The load is held by a hook pivoted at the bottom of the carriage, which hook is held by a latch. When the carriage comes in contact with the rubber buffer on the sheave block at the warship, this latch is pressed in, thereby releasing the hook and its load. Should the carriage strike heavily at either terminus, the upper part of the cable will slip through the grip and no damage will be done.

(5) As soon as the bags are dropped, the direction of the rope is reversed, and the carriage returned to the collier. During the transit of the load an elevator car descends to the deck, bags of coal are placed thereon, suspended from a bale, and elevated again to the stops on the guides, so that when the carriage has returned to the collier, the pointed hook finds its way under the bale or hanger supporting the coal bags. The instant the load is hooked on, the direction of the ropes is again reversed, the carriage takes its load from the elevator and transfers it across the intervening space to the warship, and drops it again into the chute.

There was no discussion on this paper, and the next paper, on "Reasons for the Adoption of the Water-tube Boiler in the U. S. Navy," by Rear Admiral George W. Melville, Engineer-in-Chief, U. S. N., was read. The discussion brought out very little information in addition to what was given in the paper. The next paper was by Mr. John Hyslop, and had been written in response to the invitation issued by the society at its meetings of November 10 and 11, 1898, asking for papers on the subject of "Life Saving at Sea." In discussing this paper, Captain

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George Randle, of the Atlantic liner *St. Louis*, suggested the adoption of very large ship's boats, capable of holding say 100 persons, carrying them athwartships on ways and launching them endwise on chutes exactly similar to the way in which ships are launched from the building ways. Captain Randle stated that experiments which he had seen conducted had convinced him that the plan was perfectly feasible.

The next paper was by Naval Constructor J. J. Woodward, U. S. N., and described in considerable detail the electrical installation on the new United States battleships *Kearsarge* and *Kentucky*. These are the first vessels of our navy on which the use of electricity as a motive power for the ship's auxiliary machinery has been adopted extensively. The only auxiliaries operated by steam on these two vessels will be those connected with the main propelling engines such as air, feed and circulating pumps, forced-draft blowers, ash hoists, etc., and the windlasses and steering engines. The discussion on the paper was very short, and turned chiefly upon the relative advantages of the two-wire and three-wire system of distribution for such conditions as prevail on board warships.

The next paper was read by Mr. Geo. W. Dickie, of the Union Iron Works, San Francisco, Cal.

A Simpler Arrangement for the Mechanical Apparatus on Warships.

The present complicated condition of affairs in the arrangement of the various mechanical contrivances used on modern warships is due to two causes, as follows:

(1) Uncontrolled growth of new devices for doing the many things for which mechanism is required on these vessels, without the new devices being considered reliable enough to supersede the old. Hence, duplication and, in many cases, triplication of apparatus for doing one thing, for which one good device alone should be used.

(2) The system of divided control over the work, rendering it impossible to have a homogeneous design to begin with, that would enable the ship and all that is required of her to be treated as one machine, and provision made at the start for every function being considered with relation to every other function.

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As a remedy, an arrangement is suggested, consisting in the construction of a tunnel or passage lengthwise of the vessel at the center and just below the protective deck, and the installation of all pipes and wires in this passage. From this central passage the pipes and wires branch off on each side to the various mechanisms located throughout the ship. All steam pipes are confined to the main-engine room, the auxiliary-engine room and electric-generator room, and all machinery outside of these rooms is operated by electric motors. The drainage pumps are electrically operated, and are located in six groups of three pumps each at regular intervals lengthwise of the central passage. The suction mains for these pumps, two in number, are located on each side of the center-line bulkhead just above the bottom stiffener brackets and the various suctions branch off transversely. The laterals and standpipes from the fire mains are arranged in a similar manner to the suctions from the drainage mains. Doors at frequent intervals in the central passage give access for repairs, inspection, etc. In conclusion, the duplication of devices for doing the same work is condemned, and it is urged that the duplication be abandoned. The use of mechanical arrangements for closing bulkhead doors singly or in groups from a central station at a distant part of the vessel is condemned as a useless and objectionable complication of apparatus.

The Wooden Sheathing of the U. S. S. *Chesapeake*.

The *Chesapeake* is a practice ship being built at the Bath Iron Works, Bath, Me., for the U. S. Naval Academy, and launched June 20, 1899. One notable feature of the vessel is that the steel hull is entirely sheathed with wood. The woodwork comprised a keel of teak, and a false keel of oak spiked to the main keel, which in turn was fastened to the metal keel plate with 1⅜-inch brass screw bolts. The sheathing proper is of 4-inch Georgia pine, except for the two top strakes, and near the stem and stern, where 3½-inch planks are used. The upper edge of the sheathing, which reaches 26 inches above the water line amidships, with an up-sheer forward and aft of 15 inches and 12 inches, respectively, is covered with a 3-inch by 3-inch angle. The planking is

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fastened to the steel hull with ¾-inch naval-brass screw bolts. Before applying the sheathing the metal hull was carefully cleaned and a thick coat of red and white lead was applied, and after the sheathing was applied a special putty was injected through holes bored in the planks into the space between the planking and the steel hull. The mixture injected consisted of 63.57 per cent. white lead, 32.1 per cent. dry red lead, and 4.32 per cent. linseed oil. Altogether 6,857 pounds of this mixture was pumped between plating and planking. The injected putty was confined to a series of longitudinal sections in the following manner: Each third strake of planking, commencing with the top of the garboard strake, was lightly chinked with a thread of oakum before the next strake was put in place. The brass screw bolts were composed of 62 parts best selected copper, 37 parts Silesian zinc and 1 part tin. The specifications required these bolts to be bent cold to an angle of 40 degrees without cracking or fracture, and to have a tensile strength of 42,500 pounds per square inch. The mean of 21 test pieces gave an average tensile strength of 47,204 pounds per square inch. The heads of the bolts were countersunk and packed with hemp grommet and red lead putty, and were fastened by a nut and washer inside the iron hull plating. The counter sink of the bolt heads was filled with Portland cement. The total weight of the sheathing and its attachments was 174,196 pounds, of which the metal used comprised 11,883 pounds. The approximate area of sheathed surface was 7,583 square feet.

Second Day's Session.

After some routine business the reading and discussion of papers were resumed. The first paper was read by Mr. W. I. Babcock, manager Chicago Shipbuilding Co., and described the duplicate mold system of building vessels employed at the yards of that company, and to a greater or less extent in other shipbuilding yards on the Great Lakes. The contents of the paper being of special rather than of general interest, and it being difficult to abstract it satisfactorily, we shall refer such of our readers as wish to study it carefully to the published proceedings of the society where the details and illustrations can be examined. In

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discussing this paper, Mr. George W. Dickie, of the Union Iron Works, called attention to the great simplicity of design and construction which had been developed in the building of ships for the bulk freight service of the Great Lakes. Some of these features he thought could be studied to advantage by marine architects with a view to their adoption in or adaptation to the design and construction of seagoing ships. A number of other members who had had experience with the duplicate mold system described in the paper confirmed the opinion of the author regarding its convenience and economy.

The next paper was presented by Mr. James Dickie, Union Iron Works, San Francisco, and described the system of overhead cranes and side stagings used at the works of that company.

Shipyard Building Slips with Overhead Crane and Staging Arrangements.

The need of some means by which material can be hoisted and deposited in any position on a vessel while it is under construction has developed a number of overhead devices which are now in general use in shipyards. These devices are of comparative recent development. Previous to 1884 the only means used to hoist material on a vessel while building was the derrick pole with the swinging gaff. Among the forms of cranes now in use are the following: (1) The cantilever crane, of which the one employed by the Newport News Shipbuilding Co. is a good example; (2) the overhead crane or gantry, so much used on the Great Lakes, which travels all over the vessel, with rails on the ground on each side; (3) the large gantry employed in building the *Oceanic* at the works of Harlan & Wolf, at Belfast, and (4) the overhead framework construction such as is used at the works of Swan & Hunter, in England, and the Union Iron Works, at San Francisco. At the Union Iron Works there are four of these frameworks in use. The framework consists of a series of bents which are placed about 12 feet apart and form a skeleton steel-like structure over the vessel. The bents are firmly braced together longitudinally, and the entire framework is 408 feet long and 78 feet wide. A 50-foot crane at each end

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enables the framework to cover a vessel 500 feet long, and for longer vessels the framework can easily be lengthened by adding bents at the ends. The whole length of the framework is traveled over by two bridge cranes, and the jib cranes are spaced at such intervals along the sides that their fields of operation overlap each other. The paper continues the description as follows:

The apex of the roof is 3 feet from the center, making one crane 6 feet longer than the other. This is done to enable pieces, such as beams, etc., to be landed on the center line. The cranes are electric and travel at the rate of 180 feet per minute fore and aft, and 90 feet crosswise, and the hoisting speed is 90 feet per minute, with a lifting capacity of 5 tons. A manila rope is used for hoisting, which gives considerable elasticity, and enables a plate to be bolted up if within an inch or two of the place. For plating under the bottom and under the counter we use a wire rope, rove through the plate and the corresponding hole in the frame and toggled under the plate, which enables the plate to be drawn close up to its place.

One feature of the structure is the facility with which staging can be erected. Where the ship is large, the spauls, which are 4 by 8 inches, are rove through the main posts and held by loose bolts at the ends. Where the vessel is narrower, a standard made of 3 by 6 inches double is set on top of the ground, and held from canting by the rigidity of the spaul in the posts, thus saving all bracing. As the posts are all 12-foot centers, we use 2 by 12 inches by 26-foot plank for staging, which we find strong enough for any work, and light enough to be easily handled.

We propose, in our new slips, to fit up cranes for riveting. These cranes are made of 8-inch T-bulb beam, and are supported by two suspension rods. The trolley for the riveter runs on the lower flange of the beam; the wheels being 20 inches in diameter makes it very easily moved.

The machines we are at present using are the toggle-jointed air machines, which drive $\frac{7}{8}$-inch rivets with a 30 inch gap. The weight of the machine is about 1,400 pounds. It moves so easily that the operator has no difficulty in making the nicest adjustment. We are also using the percussion air machine, with a 4 or 6-foot gap, which weighs only about 250 pounds. As will be noticed, the cranes for riveting are only 32 feet long, with a beam hung from them. This enables us to do hoisting and riveting at the same time, as all the material is hoisted up over the vessel

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and carried along near the center line to a point opposite to where it is to be landed. This center cross-beam can be raised or lowered to suit the work on the vessel. When working on the inner bottom it will be down; when on deck it will be close up to the cranes.

We have studied all the various overhead cranes and claim for this structure that it is no more expensive in first cost and fulfills more functions than any other, except the one at Messrs. Swan & Hunter, on the Tyne, and in comparison with it I think we have the advantage in staging. We find no disadvantage in having the posts as close as 12 feet, all the hoisting being done at the upper end, then carried over the vessel to the required place, and, when there, lowered into its proper place. As we use no side shores above the bilge, the top sides are always clear for lowering a shell plate into position, and, as I said before, the bottom plates and plates under the counter are hoisted from the ground with a wire rope rove through the corresponding hole in the frame, and toggled outside the plate; thus the entire plating can be put on the vessel with these cranes.

We have two cranes at the upper end of the structure. These we use for frame riveting and all other pieces that can be riveted before going on board.

As mentioned before, we use the structure to keep the upper works of the vessel fair while in the early stages. For fairing the upper works we use turnbuckles from the sides of the vessel to the structure, and pull in or slack out when necessary. All of which is done by the men on the upper stage, at small cost and with much convenience.

In discussing this paper, Mr. John Platt pointed out that there was some misconception of the purpose of the Harlan & Wolf gantry crane employed in building the *Oceanic*. This crane was in the first place intended only for use in building very large vessels, and, second, it was designed purely for carrying riveters, and not for handling materials. The material was all handled on the ground alongside the vessel by cars, and was hoisted on board by derricks. The gantry was used for riveting only, and that it seems to have proven successful for this purpose was evidenced by the fact that Harlan & Wolf are building two more exactly similar, except for some slight changes in dimensions.

The next paper, describing the "Designs for the *Denver* Class Sheathed Protected Cruisers," for which bids have recently been

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received, was by Rear Admiral Philip Hichbórn, Chief Constructor, U. S. N. In a written discussion Chief Engineer George W. Melville deprecated the fact that the writer of the paper should have felt called upon to defend the design of the new cruisers against newspaper criticisms. He also thought the implied criticisms of the cruisers of the *Raleigh* and *Cincinnati* class were somewhat unfair, and said:

The *Cincinnati* and the *Raleigh* were designed at a time when there was a perfect craze for big speed in all classes of vessels. The statement had been dinned in our ears so much so that we must get at least as good results from every ship as were obtained from foreign ships, and must, if possible, do better, that our designers were working, as one might say, under the lash. Just before the designs were prepared the British Admiralty had got out designs for what were known as the "M class of cruisers," which were exactly the characteristics of the *Cincinnati* and the *Raleigh* in the way of putting a large power in a small hull and aiming at a very high speed. The history of those ships has been very much the same as the history of ours, in that they have not been a brilliant success.

Respecting the speed of the *Raleigh*, Admiral Melville pointed out that her speed of nine knots shown at Manila was obtained after she had been six months without cleaning, and that after she was cleaned at Hong-Kong she regularly made an average of twelve and thirteen knots for long distances on her run home from Manila.

Referring to the question of speed, Mr. George W. Dickie, Union Iron Works, commended the courage of the Navy Department in reducing the speed of the new cruisers to sixteen knots and giving the vessel greater coal endurance. He regretted, however that a soft wood like pine had been adopted for the sheathing. A hard wood like teak was far better and but a very little more expensive. Naval Constructor Francis T. Bowles expressed himself decidedly as being against sheathing for a steel vessel. It might be necessary as long as a considerable number of vessels were required in the far East, but only until a dry dock could be built there.

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The next paper was read by Assistant Naval Constructor R. M. Watt:

NOVELTIES IN SHIP FITTINGS.

This paper described a number of new devices in fittings which have recently been employed in some of the vessels of the U. S. Navy. The novelties described include a water-tight metal skylight for use over messrooms and staterooms; a metallic folding berth for ships' staterooms; an asbestos sheathing for finishing staterooms and living quarters; and an electrically-operated watertight bulkhead door. The new bulkhead door is similar to the watertight sliding door devised by Mr. W. B. Cowles ("Eng. News," Aug. 18, 1898), fitted for operation by electric power instead of by hydraulic power.

The motor used is 1-H.P., compound-wound, of the short-shunt type, the short-shunt coils being relatively weak, and wound outside the series coils. The circuits are so arranged that for raising the door, only the series coils are in circuit, giving quick and easy starting, while for closing the door where it may be necessary to cut through coal, the shunt and series coils are both in circuit.

The electric current taken from the mains passes through a three-point spring-lever switch. Moving the lever to the right or left completes the circuit through the motor and raises or lowers the door. The shaft of the switch handle pierces the bulkhead so that the switch may be thrown from either side. A spring returns this lever to its central position, and when in this position, the door-closing circuit may be completed from one or more distant stations in any part of the ship. The door-opening circuit can be completed only at the door, and when completed cuts out the closing circuits.

Beyond the spring-lever switch, the circuit contains a limit switch opened by a bell-crank lever when the door reaches either of its extreme postions. The shaft of the pinion that engages in the door rack, carries at its end another pinion that gears into a spur wheel keyed to a shaft that carries the bell-crank levers for working the limit switches. The position of these levers may be adjusted for varying the lift of the door.

Beyond the limit switches, the circuit contains two Sprague solenoid gravity controllers which throw in either the series or the series and shunt fields of the motor. These controllers have

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carbon and copper contacts, which prevent pitting of the copper bars, but necessitate occasional adjustment of the carbon tips. The controllers are fitted in a watertight receptacle with a hand hole and glass cover; this allows constant inspection of the carbons, and their adjustment when necessary, without removing the front of the receptacle. The working of the controllers is easy and simple, and there are no springs or pins; the copper bars are carried on phosphor-bronze flexible plates allowing for a little wear of the carbons without readjustment, and ensuring good contacts. All the parts are enclosed in watertight boxes.

Speaking of the progress made in the task of rendering ships' fittings free from danger from fire, the paper gives the following interesting summary of present practice:

Six years ago the divisional bulkheads were of untreated wood; likewise the ceiling overhead and the ceiling or sheathing against the side of the ship. The berths, lockers and all the furniture, including a closed-in wardrobe, also the ship's ladders, shelving everywhere, etc., were of untreated wood. Now, the constant endeavor is to reduce woodwork everywhere to a minimum, steel or some other non-combustible material being substituted wherever practicable, and where wood is used at all it is required to be subjected to an approved fireproofing process. The present practice at Brooklyn Navy Yard is as follows: The unnecessary overhead ceiling is altogether omitted. In crew's quarters the outboard sheathing is omitted, but in officers' quarters asbestos sheathing is fitted. All divisional bulkheads are built of light corrugated sheet metal (first fitted on the *Texas* in 1892) and finished with a sheet-metal cornice (first fitted on the *Atlanta*). The uncleanly wooden berth is replaced by a compact and cleanly metal folding berth. The wooden ladders are altogether done away with, and metal ladders with some form of non-slipping tread are in general use. For the unsatisfactory wooden skylights over messrooms and inboard staterooms a watertight metal skylight is substituted. At the present time the desks, chairs, tables and chiffoniers used on naval vessels are made of fireproofed wood; but samples of metal furniture, by which the use of wood for this purpose will be entirely dispensed with, are now being prepared at the Brooklyn Navy Yard for the purpose of selecting types for naval use. All lockers supplied to the *Atlanta*, including rifle lockers, petty officers' lockers and marines' lockers, are of metal, and the *Atlanta's* cabin has been fitted with a metal roller-top desk.

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In the discussion which followed, a member called attention to the fact that in the new Russian war vessels now being built at the Cramps' yards, all the sheathing was asbestos, all the furniture except the chairs was of metal, and the deck planking was the only woodwork in the whole ship. Mr. W. B. Cowles spoke at some length regarding the comparative advantages of hydraulic or pneumatic power and electric power for operating bulkhead-doors. He thought that either hydraulic or pneumatic power lent itself more directly to the work to be performed than did electric power, and was more cheaply transmitted. He also criticised some of the details of the door-tightening apparatus described in the paper. The next paper was by Lieutenant A. B. Niblack, U. S. N.

Tactical Considerations Involved in Torpedo-Boat Design.

The highest development of the present type of torpedo is one about 16 feet long and 18 inches in diameter, and carrying a charge equivalent to 110 pounds of gun cotton. The highest pressure used in the air flasks to operate the engines is 1,500 pounds per square inch, giving a speed of 30 to 32 knots at 400 yards, 28 to 30 knots at 800 yards, and 26 knots at 1,000 yards. Some unusually long torpedoes for coast defense run as high as 30 knots for 1,000 yards and 24 knots for 2,000 yards. The torpedo is not a delicate instrument. Recent inventions and improvements have worked a complete revolution in the status of the torpedo. The first improvement is the application of the principle of the gyroscope to the steering rudders of the torpedo, and the second is the perfection of apparatus that will safely and accurately launch torpedoes from the under-water broadside of a rapidly-moving ship. The latter invention practically does away with above-water discharge in large ships, and the former has doubled the accuracy of fire.

Torpedo-boat attack, to be reasonably certain, must be a surprise. Attacks are made in groups of boats, and a single boat would attack only as a forlorn hope. A successful attack is, therefore, a question of team work.

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In approaching to the attack, previous to discovery, reduced speed must be used so as to avoid white bow waves, smoke and flame, and that peculiar and far-sounding hum which accompanies fast-running machinery. Once discovered, or once within striking distance, high speed becomes important, but it takes some little time to attain it after having once slowed. As between a speed of 20 and one of 30 knots the time it takes to cover 1,000 yards is only as 90 seconds to 60 seconds. Can the 30-knot boat pass from 20 to 30 knots in 30 seconds? If you can build three boats of 22 knots for what two of 30 cost, and if the greater the number of attacking boats the better the chances, is it not wise to forego phenomenal speed? This craze for great speed is illogical, and tactically it is indefensible. Back of it is generally an advertisement for somebody. People who handle torpedo boats have never sanctioned it. What they do ask is that boats be built in groups on identical designs, and that every reasonable effort be made to standardize fittings. As long as fittings are standardized, we may improve groups progressively from year to year as experience dictates.

The vast majority of torpedo boats are single-screw boats. Single-screw boats with bow rudders handle quite as well as twin-screw boats without, and it is claimed for the single-screw boat that there is a saving in oil and the number of men required to operate the machinery; there are fewer moving parts and less liability of breakdown, and the weight and dimensions of the machinery are smaller.

As torpedo boats abroad are frankly intended to maneuver or cruise in groups, questions of spare parts, breakdowns, shortage in supplies, etc., are not so serious, since the boats rely on one another somewhat in cases of emergency. Probably no country has developed her torpedo-boat system so thoroughly as Germany. Fully 90 per cent. of her boats were built by Schichau, and the custom is to order them in groups of eight, all practically of similar design and with interchangeable parts. The tonnage has gradually increased from 85 to 140, as at present. Six of these boats form a group for maneuvering purposes, so that two of the eight are kept in reserve to take the place of any that may come to grief. There are ten large division, or "D" boats, of from 250 to 380 tons displacement, and from 1,800 to 5,500 H.P. They are each a sort of flagship, or "mother" boat,

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for each group of six smaller ones, and accompany it everywhere. This division, or "D" boat, carries the heavier spare parts for the six accompanying boats, such as cylinder heads, piston rods, propellers, and a reserve supply of stores and fittings. Each "division" has its headquarters at a certain navy yard, and has a group of small storehouses at the water front, one for each boat, including the "D" boat and the two in reserve. When a whole division is in the second reserve all the stores of each boat are in its own storehouse, and the group of boats is tied up near the group of storehouses. Any deficiency in stores or fittings are made up from the large central torpedo storehouse, where all articles are standardized. In the winter the boats in reserve are kept at a uniform temperature by means of steam coils, connected with the shore by piping. Only when repairs are needed are boats hauled out, so that the division may always be ready to be put into commission for trials in twenty-four hours, and ready for war in forty-eight. If in drills or cruising a boat is injured, it is astonishing to see how quickly a spare boat of the group is forthcoming, and ready with the crew of the injured boat. Boats in the second reserve are looked out for by the navy-yard force, and a vessel under repair is always on the second reserve.

Oil fuel recommends itself for torpedo boats as compared with coal, for numerous reasons. Moderate reliable sea speed coupled with a large capacity for carrying and distilling fresh water is the fundamental requirement for a torpedo boat.

All this suggests the question, "What are the desirable characteristics of a first-class sea-going torpedo boat?" The answer here given is:

(1) It should be as small as is consistent with sea worthiness, so as to offer as small a target and be as little visible as possible, and, at the same time, should offer a reasonably stable platform for its torpedo tubes.

(2) It should be designed to have as small a bow wave as possible; its machinery should be as nearly noiseless as practicable; and it should not show flames or smoke from the stacks.

(3) It should have a large fresh-water tank capacity and be fitted with two smaller evaporators and distillers in preference to one larger one.

(4) It should have a reasonable bunker capacity. If for coal, the design should have in view the future use of liquid fuel.

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(5) The efficiency of the boat depending so largely upon the physical condition of the crew, habitability should receive due consideration in the design.

(6) Speed is not essential, although desirable, but a moderate, reliable sea speed, obtained without forcing and without noise, flame and vibration should be striven for.

The discussion which followed this paper turned almost entirely on the question of speed, and the opinion was very generally expressed that in seeking for exceedingly high speed for torpedo boats many far more essential qualities had to be sacrificed, such as habitability, strength and endurance, coal capacity, etc. It was also pointed out that too many different kinds of service had been demanded of torpedo boats in actual employment. They had been required to do blockade duty and to act as despatch boats, and required to keep at sea in all sorts of weather. The result had been that they had suffered damage, and had to be repaired. The experience of the Spanish-American war and the Cretan blockade by the English during the Greco-Turkish war had shown conclusively that the modern torpedo boat would wear itself out in a very short time when called upon to do continuous duty at sea.

The papers on the "Progressive Speed Trials of the *Manning*," by Professor Cecil H. Peabody, and on "The Action of the Rudder," by Professor Wm. F. Durand, were presented briefly in abstract by their authors. Both papers were of a mathematical character and were only briefly discussed. The same statement is true of the paper on "Beam Formulas Applied to Vertically-Stiffened Bulkheads," by Mr. H. F. Morton. The convention closed with a banquet on the evening of the last day's meeting, at which there were a number of invited guests.

During the first session the following officers were elected for the ensuing year: President, Clement A. Griscom; First Vice President, W. T. Sampson; Vice Presidents, Francis M. Bunce, Charles H. Cramp, Frank L. Fernald, Philip Hichborn, Geo. W. Quintard, Irving M. Scott, Edwin A. Stevens; Secretary and Treasurer, Francis T. Bowles.

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CAPACITY LIMITS IN DIRECT-CURRENT MACHINES.

In electrical machinery the maximum possible rate of work is far beyond the practical limit. A steam engine, at a given speed, cannot work at a greater rate than that which corresponds to boiler pressure through the entire stroke of its piston. If heat can be got rid of fast enough to prevent destruction of its materials an electric generator or motor does external work at its maximum rate when one-half of the electric energy generated in, or applied to, the armature coils is wasted there as heat. In this case the efficiency of the machine, disregarding the losses in magnet coils, local currents, hysteresis and friction, is 50 per cent. As the normal losses in armature windings of large and medium-sized machines is usually from 1 to 3 per cent. at full rated load, the enormous increase possible is evident. As a matter of practice, none save experimental or very small machines, are ever built in which the maximum rate of work above indicated could be realized. The two practical limits of capacity in direct-current dynamos are determined by the heating of the conductors and sparking at the brushes. The electric circuit, consisting of the windings, in an electric machine is separated from the other metallic parts by cloth, paper and other materials which may be injured by heat. This insulation is absolutely essential to the operation of the machine. It is found, as a matter of experience, that cloth and paper when kept in contact with metal at much above 250 degrees Fahrenheit, rapidly deteriorate in insulating properties and mechanical strength. This fact makes it imperative that the maximum rise in temperature of an electric machine, plus the temperature of the surrounding air, shall not exceed the limit of 250 degrees Fahrenheit.

Dynamos and motors are apt to be operated in basements and engine rooms where the temperature is as high as 120 degrees Fahrenheit, and it is common in good practice to limit the maximum rise above the surrounding air, in the windings of electric machines to 90 degres Fahrenheit. As the heat developed in armature windings varies as the square of the current, that is, as the square of the rate of work, the maximum temperature rise increases rapidly with the rate of work, in a given machine. The

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rise in temperature that will take place in a particular machine under continuous operation at a certain load depends on the rate at which the parts of that machine dissipate heat. As is well known, a body in free air dissipates its heat the faster, the higher its temperature above that of the surrounding air. Complying with this law, the windings of electrical machines, when put in operation at first, give off but little heat, and the temperature increases up to the point where the energy expended in the windings just equals that dissipated as heat. In small machines the maximum rise of temperature may frequently be reached in three or four hours' run at full rated load, while in large sizes the time usually extends to ten hours or more.

An electric machine may, however, be brought to its maximum temperature for rated load by operation during a shorter period than would be necessary with that load at a properly determined greater load. It is at once evident from the above, that rise of temperature in the windings is but a slight limit to momentary overloads or even to those of some few minutes' duration, since a comparatively small amount of heat is generated in the coils during these short periods by the extra load. The heat limit to capacity in electrical machinery thus requires a considerable time for its operation, and is cumulative, tending to the destruction of the insulation.

The limit imposed by sparking at the brushes is immediate in its action and but slightly destructive, while, intimately connected with it are tendencies to reduce at once the output. To understand the phenomenon of sparking and its production by an overload, a glance at the function of a commutator is necessary. In a direct-current generator of ordinary construction the commutator is but a series of connections to the armature coils at stated intervals, for the purpose of brush connection. This fact is well illustrated by the practice of two well-known makers, who in some large machines arrange the brushes for direct contact on the bars forming the armature winding.

That part of the armature winding with which the brushes makes direct connection is subjected to a reversal of the current flowing in it at the time it passes the brush, since the current divides at

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the brush contact, one-half flowing through the winding in each direction. The strength of the magnetic field through which the conductor is moved must have a certain relation to the current flowing through the conductor, if reversal is to be accomplished without sparking at the brushes. In all well-designed dynamos the distance between the face of the pole-piece and the iron of the armature coil is proportioned with special view to sparkless commutation, thus making its length much greater than is usually necessary for mechanical clearance. This air gap generally requires about 70 to 90 per cent. of the exciting power of the magnet windings, the remainder being utilized to force the magnetic flux through the iron circuit of the machine. As the magnet winding requires more copper than any other part, and constantly consumes energy while the machine is at work, it is desirable to keep the magnetizing force required for the air gap as small as consistent with good operation. To allow for temporary overloads, however, it is customary to so design apparatus that the sparking limit allows somewhat greater output than the heating limit. This last is particularly true in machines intended only for intermittent work, as crane motors, where an all-day load, quite within the sparking limit, would seriously injure the insulation of the windings.

An excessive current in the armature coils produces sparking, and this latter is usually obviated in some degree by changing the angular position of the brushes on the commutator to a point where the commutating coils will be in a stronger magnetic field. A reaction of the armature on the magnets results from the brush movement just noted in such a way as to decrease the total magnetic flux and, consequently, the electric pressure and output in the case of a dynamo.

Detection of overload through rise in temperature requires some time and careful observation, but when the sparking limit is exceeded the trouble is at once apparent.—Alton D. Adams, in "Engineering News."

MISCELLANEOUS.

Petroleum Motors.—The high economy which may be obtained by the complete combustion of liquid fuel in an internal-

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combustion motor is now generally conceded, and as a result there have been numerous attempts to design motors which shall prove acceptable for general use. The Diesel motor has been fully noticed in these columns at various times, and now we have the Dopp motor, which was discussed at a recent meeting of the Verein deutscher Maschinen-Ingenieure, the account being published in "Glaser's Annalen."

Dopp maintains that the high compression advocated and used by Diesel is not necessary to the attainment of superior thermal economy, and claims that equally good results can be secured by the use of vaporized petroleum, drawn into the cylinder with the proper proportion of air, and burned under practically the same conditions as obtain when gas is used in a well-designed gas engine.

It seems to be generally admitted that the main element in the economy of a petroleum motor lies in the complete combustion of the fuel. While this is secured by providing a compressed atmosphere, it does not appear that it is necessary to use a compression materially greater than is now employed in the gas engine. The Dopp motor does not differ in general construction from an ordinary gas engine, except that the petroleum fuel is gasified by the heat of a lamp before it is drawn into the cylinder, and the excellent economy which appears in the regular service is claimed to be due only to the completeness of the combustion, attained by a thorough mixture of the fuel with the proper quantity of air.

Herr Dopp gives figures from a number of his motors in daily use which show a consumption of 0.197 to 0.240 kilogrammes of petroleum per horsepower hour, the lower result being obtained with a 10 horsepower motor after it had been in practical service for more than eleven months. This result is better than was attained by the Diesel motor of twenty horsepower tested by Professor Schroter, although under less favorable conditions.

Herr Dopp maintains, as has been claimed by others, that the Diesel motor by no means realizes in practice the theory enunciated by its designer, and shows that some of the fundamental

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points which, according to the theory are essential to the highest economy, are distinctly controverted in the working of the motor. From this he deduces that the high economy of the Diesel motor shows that the theory is not sustained.

An important feature of the motors constructed by Herr Dopp lies in the fact that they can be constructed and operated in a satisfactory manner for small powers, good results being obtained with motors of two to five horsepower, while the construction of the Diesel motor is such that it does not appear advisable to make them for less than twenty horsepower.

Regardless of the theoretical questions at issue, there seems to be little doubt that very simple, efficient and convenient petroleum motors can be made upon the same general design as that already in public use for gas, and that care in design and in the correct proportion of air to fuel supply can, with a moderate degree of compression, insure such a complete combustion as to leave little or no trace of soot either in the cylinder or in the exhaust gases. Under such circumstances there can be little doubt that the petroleum motor has a most useful future before it, especially for small powers.—"Engineering Magazine."

PULVERIZED FUEL.—The attention which is now being directed toward the prevention of smoke in connection with the generation of power by the combustion of coal has awakened renewed interest in the possibilities of pulverized fuel. An exhaustive review of the past and present practice in this branch of engineering appears in a series of articles in the "Schweizerische Bauzeitung," and in view of the schemes which have recently been discussed, this review is of present value.

Pulverized fuel has been the subject of experiment since 1831, when Henschel, at Cassel, charged air with coal dust and used it for firing brick kilns, and for welding and for other smithy operations. Nearly thirty years later Pütsch attempted to use coal-dust firing for glass furnaces in England, and in the 70's Crampton made a number of applications of the principle to metallurgical operations.

In America the experiments of McAuley about 1881, and Hath-

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away in 1886, are well known, and at the present time the experiences of Wegener and others in Germany and elsewhere are attracting considerable attention.

Three fundamental principles are laid down for the successful use of pulverized coal as fuel. (1) The combustion chamber must be maintained at a high temperature; (2) the powdered fuel must be delivered into the midst of the entering air current, and the intimate mixture of air and fuel delivered into the combustion chamber in an uninterrupted stream; (3) the particles of coal must be maintained suspended in the air until they are fully consumed.

This last condition is very important, since if the particles fall out of the air current to the bottom of the combustion chamber mere coking will take place instead of a complete combustion.

A distinction must be made between powdered fuel and the ordinary coal dust which is found at every mine. The coal for use in air-blast firing without grates must be finely ground in a mill, so that it will pass a sieve of 900 meshes per square centimeter, and must be entirely free from any larger particles.

The first of the above conditions requires especial consideration in connection with internally-fired boilers, since the proximity of boiler surface to the burning dust will chill the furnace to an extent sufficient to make the combustion imperfect. In order to avoid this it is necessary to line the furnace with fire brick, which, by attaining a high temperature, prevents the chilling of the flame and acts to equalize the temperature. There is no loss of heat by using such a lining, as the fire brick occupies only an intermediate position and the heat is ultimately transferred to the boiler surface.

The second condition, that of mixing the fuel with air and feeding the mixture into the combustion space, is the one which must be fulfilled by the construction of the apparatus, and the ingenuity of designers is mainly exerted in this direction.

The third condition is mainly dependent upon the fineness of pulverization, and it is the cost of grinding the coal to the necessary degree of fineness which usually limits the commercial application of any process.

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The Wegener furnace, about which much has been said of late, is an attempt to apply pulverized coal methods similar to those which have been used successfully with low-grade hydrocarbons, and with petroleum refuse, in Russia. In this apparatus the finely-powdered coal is distributed into the incoming air by a revolving sieve, and the mixture is then driven into the combustion chamber by a steam jet. A firebrick lining permits the high temperature to be maintained, and as this soon becomes white hot, any slight inequality in the rate of firing does not permit a sudden chilling. The ash which exists in the coal is mostly fused to a liquid slag, which runs out a tap-hole below, and it is found that there is no greater accumulation of dust in the boiler flues than occurs with ordinary firing.

A number of tests, conducted with especial regard to smoke-prevention, have been made in Germany, and the details of these do not show any extraordinary evaporative performance, from 8 to 9 pounds of water per pound of coal being the average result. The absence of smoke was practically attained in all cases, however, whenever proper precautions were taken to provide sufficient fire-clay surface in the combustion chamber to prevent chilling of the flame. This has been found difficult of accomplishment in the case of water-tube boilers, unless an entirely separate combustion furnace is constructed, since the presence of the tubes containing water checks the combustion to an extent sufficient to cause smoke to be produced.

The use of pulverized fuel can hardly be recommended on the score of economy, as the evaporation is little if any higher than that obtained by ordinary firing, while at the same time the cost of grinding the coal must be included. When, however, it is imperative that no smoke be produced, it appears that this is one of the various methods by which that desirable result may be attained.

SMOKELESS COAL.—A "smokeless coal" of recent invention has just been tested in England. In the course of the experiments, which are described in "La Nature" (July 22), the new combustible "was burned in ordinary grates and also in braziers

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placed in the middle of the room, and it was found that it gave off only traces of smoke, which was hardly perceptible even when fresh coal was added to the fire. The fire resembled an extraordinarily brilliant coke fire and had long white and blue flames. The heat given off is intense, and as to the production of steam, one pound of coal evaporates fourteen pounds of water. The residues (ashes, etc.,) do not exceed 3 per cent. For industrial use, the combustible is molded into perforated bricks weighing about ten pounds apiece, but for domestic use it takes the form of cakes or lumps of lenticular form, of which 140 weigh 100 pounds. At present the bricks can be bought in London at retail for 21s. ($5.25) a ton. We are told that the new combustible is composed of 93 per cent. of coal dust and of 7 per cent. of a mixture of pine and caustic lime. These three substances are mixed and run into molds, where they harden to such a degree that they do not separate in burning."—Translation made for "The Literary Digest."

WESTINGHOUSE BRAKE.—About a year since the Russian government determined to apply air brakes to freight trains upon the State railways. The Westinghouse Brake Company, Limited, of England, entered into negotiations with the Russian government with a view to furnishing the air-brake equipment; and when sufficient assurance of business was received, with the condition that the brakes should be made in Russia, a new company—the Société Anonyme Westinghouse—was formed, a manufacturing site in St. Petersburg was purchased, and the installation of manufacturing plant was begun. About the close of 1898, an order for air brakes, amounting in value to £400,000, was given to this new brake company by the Russian government. In January of the present year a congress of the engineers of all the private as well as all the Russian government railways was assembled, and, after due consideration, it was decided to adopt the Westinghouse brake system as the standard for all the private as well as the Imperial lines. On June 5 an Imperial decree was issued as follows: 1. All freight locomotives and tenders, and a sufficient number of freight cars to secure brake control of all

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freight trains within the Russian Empire, must be equipped with air-brake apparatus prior to January 1, 1903. 2. The Westinghouse air brake has been adopted, and must be purchased for this purpose by all roads, private and State. 3. The use of any other kind or make of air brake than the Westinghouse is prohibited, with the provision, however, that a trial of any other brake system may be made in connection with the Westinghouse upon local lines.

JAPANESE BRIDGES.—The Pencoyd Iron Works of Philadelphia, has secured an order for a very large bridge for the Japanese Imperial government railways. The bridge will be 6,913 feet in length, and it will absorb between 7,000 and 7,500 tons of material.—"Engineering."

LIQUID FUEL.—The output of liquid fuel, or masut, and of petroleum by-products has now become the mainstay of the petroleum industry in Russia. The annual quantity of masut consumed amounts to no less than 500,000,000 poods, which, with the extension of the railways, is expected to further increase to a large extent. Not only in the firing of locomotive boilers liquid fuel is playing an important part, but also in connection with the raising of steam in marine boilers. As a preliminary, all the war vessels belonging to the Baltic fleet are now fired with liquid fuel, and it is believed the whole of the Russian Imperial navy will eventually be converted to the system, according to a gradual process of transformation. The industry is at present hampered through lack of a sufficient number of tank steamers.—"Marine Record."

CAST ALUMINUM is about equal in strength to cast iron in tension, while under compression it is comparatively weak. With a purity of 99 per cent. the ultimate tensile strength of aluminum per square inch is, in castings, 18,000 pounds; in sheet, 24,000 pounds to 40,000 pounds; wire, 30,000 pounds to 55,000 pounds; and in bars, 28,000 to 40,000 pounds. The elastic limit of aluminum of this purity is: for castings, 8,500 pounds; sheet, 12,500 to 25,000 pounds; wire, 16,000 to 33,000 pounds; and

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bars, 14,000 to 23,000 pounds per square inch.—"Engineers' Gazette."

"THE ADVANTAGES OF THE USE OF GAS ENGINES can be best appreciated," says Mr. George Westinghouse, in a recent pamphlet entitled "Westinghouse Gas Engines," "when it is understood that if a gas company were to supplant the present gas illumination by an equal amount of electric light, obtained from gas engines and dynamos driven by its gas, it would have left for sale, for other purposes, over 60 per cent. of its present gas output."—"American Engineer and Railroad Journal."

SUPERHEATED STEAM offers a number of advantages which are summed up by Mr. R. S. Hale, in "The Engineering Magazine," as follows: 1st. A slight gain at the boiler, although a less gain than can be obtained by increasing the boiler-heating surface, or by the use of an economizer. 2d. A large gain in economy at the engine, while as a disadvantage there is: 3d. An increased loss in the steam pipes, due to increased radiation, fall of pressure and increased leaks. With from 500 to 700 degrees temperature of the steam, Mr. Hale places the results to be obtained as follows:

Gain at boiler, per cent	2
Gain at engine, per cent	10 to 20
Extra loss in pipes, per cent	4½
Net gain, per cent	7½ to 17½

—"American Engineer and Railroad Journal."

TIN.—In view of the increasing price of tin, it is interesting to learn that the Tasmanian exports of this metal had, up to the end of 1897, aggregated 80,000 tons, the Mount Bischof Mine being responsible for about three-sevenths of this total. This mine is worked in open quarry at three separate faces, known respectively as the Brown face, the Slaughter face, and the White face. The Brown face forms a semicircular quarry over 700 feet in length. The ore consists of brown oxide of tin, and has been proved to a depth of 260 feet. The Slaughter face is of similar

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character, whilst the White face is an alluvial deposit.—"Engineering."

HOISTING ENGINES FOR MINES.—The enormous development of the copper mining industry in Northern Michigan has necessitated the adoption of very powerful hoisting engines, the depths being great and the load to be raised heavy. A fine engine of this character just erected at the Tamarack Mine by the Nordberg Manufacturing Company, of Milwaukee, is described in a recent issue of the "American Machinist." The engine is of the diagonal type, and has four cylinders, each 36 inches in diameter by 60 inches stroke, connected two and two on to two crank-pins. The main bearings are twenty-four inches in diameter by 42 inches long, and the drum is 25 feet in diameter and 24 feet 6 inches long, and is provided with spiral grooves for 1½-inch rope. These spirals are, however, only provided at the ends of the drum, since the depth of the shaft being 6,000 feet, a drum of an enormous size would have been needed to carry out the principle of the spiral drum in its entirety, and hence the middle portion of the drum is cylindrical. The total weight of the drum and shaft is 300,000 pounds. The load to be raised consists of 6,000 feet of 1½ rope, weighing 21,800 pounds, the cage weighing 4,200 pounds, two cars 4,000 pounds, and the rock mined 12,000 pounds, making a total of 42,000 pounds suspended on one rope. Part of this is, however, balanced by the descending cage. The speed of hoisting is 4,000 feet per minute. The engines are fitted with Corliss valves, the reversing gear being peculiar, but not easily explained without drawings.—"Engineering."

A HIGHLY SATISFACTORY TEST OF THE NEW 6-INCH QUICK-FIRING GUN, constructed for the American Navy by Messrs. Vickers, Sons and Maxim, has been made at the Indian Head proving ground. The first shots were fired with cordite, which in each instance gave velocities of 2,700 foot-seconds. After a sufficient number of rounds to demonstrate the fact that the velocities would exceed what was expected of the gun, Admiral O'Neill, chief of the United States Artillery Department, determined to

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obtain a comparative result by using navy smokeless powder. Accordingly, he had employed a charge that would give a chamber pressure not exceeding 17 tons per square inch, and the result obtained under these conditions was a velocity of 2,913 foot-seconds; such a muzzle energy with the pressure employed has never before been obtained. In England, with the use of cordite, this gun gave a velocity of 2,873 foot-seconds, with a pressure of 17 tons. The projectiles fired weighed 100 pounds. A gas check was used and to a considerable extent accounts for the high energies obtained, and prevents any abnormal wear due to the use of modern gun-cotton or nitroglycerine explosives. The striking energy of the gun was no less than 5,724 foot-tons, which would perforate a thickness of steel armor of 17 inches. The energy obtained per ton of gun is 768.3 foot-tons, and as a rate of fire of ten pounds per minute for long series of rounds has been easily obtained, the gun is capable of doing work to no less extent than 57,240 foot-tons per minute. The gun and its naval mount has already been illustrated and described in "Engineering," vol. lxv, pages 624 and 625, and vol. lxvii, page 76.—"Engineering."

New Steel Plant.—The Carnegie Steel Company of Pittsburg have decided to build two more blast furnaces, at the Carrie plant at Rankin, Pa. These two furnaces will be the largest ever built, and will be 106 feet high and 24 feet in diameter at bosh. They will turn out 1,400 tons of Bessemer iron every day. A new bridge will be built from these furnaces across the Monongahela river, to take hot metal direct to the Homestead Steel Works. At Duquesne Steel Works a new basic open-hearth steel plant of fourteen 50-ton open-hearth furnaces and a large blooming mill are to be built. This mill will be one of the largest ever built, and will be a duplicate of the one just completed at Homestead Steel Works. These improvements and additions will give the Carnegie Steel Company a capacity for turning out over 3,000,000 tons of finished material annually. The open-hearth plant at Duquesne will be built to furnish the trade with basic open-hearth blooms, billets and slabs.—"The Iron Age."

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SELF-STARTING SINGLE-PHASE MOTOR.—A patent was issued August 29 to Riccardo Arno, of Turin, Italy, on a means for dispensing with auxiliary starting coils on single-phase motors. The specification states that the inventor has discovered that by inserting an additional resistance into the closed-coil armature—that is, the rotor—and by imparting to the armature an initial motion of very slow speed, such as may be obtained by turning it by hand, asynchronous single-phase motors can be started without the use of a rotating magnetic field, and with only one group of coils—the mains coils—fed with current. The additional resistance must be capable of admitting of gradual reduction so as to be switched out gradually and without shocks just before the motor is gotten up to speed. Under these conditions it is stated that the strength of current during the whole period of starting will at no time exceed its strength just as the motor begins to turn. Trials carried out on large motors of 100 horsepower or more under no load, except the friction of the belt or loose pully, prove that the additional resistance to be inserted in the armature has a value which nearly corresponds to that required to absorb the effective current during the normal running of the motor under the same load. It is added that this condition is much more favorable than what takes place during the starting of asynchronous single-phase motors fed with auxiliary starting coils for the purpose of causing them to act as polyphase motors in getting up to synchronism. The theoretical value of the resistance to be inserted in the armature is $r = .414\ 2\ \pi\ n\ L$, n being the frequency and r and L the resistance and inductance, respectively, of each of the elementary armature coils. As illustrated there are three elementary armature coils, each connected to a collector ring on the shaft and, through its respective ring and brush, to a resistance adapted to be cut out by turning a three-armed lever on a rheostat, thereby gradually reducing, and finally short circuiting the resistances. To obviate the necessity of starting the rotor by means of an impluse given by the hand, means are shown whereby this can be accomplished simply by throwing in a switch, as follows: The rotor coils are rendered unsymmetrical at the instant of starting, which is done by switch-

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ing one of the coils in open circuit, which will be sufficient to cause the starting of the machine provided it be not at a dead point, and the stopping of the machine at a dead point can always be avoided by a judicious operator. This process also affords a convenient means for reversing the direction of the motor.—"Electrical World and Engineer."

THE ORIENTAL DRY DOCK, at Shanghai, is now in operation. This dock has an extreme length of 540 feet, the entrance is 80 feet wide and the depth on sill is nearly 24 feet at ordinary spring tides. A wooden caisson gate is used. The bottom of the dock, 75 feet wide, is made of 7 feet of concrete, covered with 3-inch plank; the sides are also built of concrete. The dock can be pumped out in 2½ hours by two 27 and 22-inch centrifugal pumps driven by a compound engine. The North German Loyd steamship *Konigsberg* has already been docked here, with 2,500 tons of cargo aboard and imposing a total weight of over 7,000 tons on the keel blocks. The dock yard has a frontage of 2,000 feet, with a depth of 26 feet alongside, and the yard is already equipped with extensive shops fitted with modern machinery for repairs to hull, engines and boilers. On one side of the dry dock is installed a pair of steel sheerlegs with a lifting capacity of 75 tons.—"Engineering News."

WIRELESS TELEPHONY.—"Sir William H. Preece has recently been carrying on some interesting experiments on wireless telephony," so-called, says "The Scientific American" (October 7): "Four of the poles have been erected near Carnarvon on a sand bank at the southern end of Menai Straits. Half a mile off four similar poles were erected, and half a mile farther on is a high pole supporting a coil of wire, one end being anchored in deep water. Between these points he has succeeded in transmitting the sound of a succession of taps. These taps were made with the view of sending messages by the Morse mode. They were heard at the receiving station by placing a special telephone to the ear. The system is more rapid than that of Marconi, but the sounds are not as distinct as they might be. As a matter

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of fact, it is not telephony at all, but a system of telegraphy in which a telephone is used as a receiver."

THE LABOR OF DISCOVERING A NEW ELEMENT.—What it means to discover a new chemical element in these days of minute and laborious physical investigation may be seen from the following description given by "The Imperial Institute Journal" (London), of the methods used by Sir William Crookes in bringing to light the substance announced by him last year and then called monium, but since named by him Victorium, in honor of England's queen. Says this paper:

"The method by which this latest discovery has been made affords an excellent example of the possibilities of modern research, especially in the hands of a man who commands the resources of more than one branch of science, and is able to employ the highest powers of each alternately as need arises. In addition to the chemical operations requiring the highest judgment and much manipulative skill, which were employed to isolate the substance, its identification and investigation were only possible by the application of physical methods still more complicated in their nature. The almost pure element had to be enclosed in a vacuous bulb, and submitted to molecular bombardment from the negative pole of an induction coil in the manner now familiar by the frequent exhibition of the X-ray bulb. The phosphorescent glow thus obtained was examined through a specially designed spectroscope of extreme power and precision, whose results were recorded by a photographic plate, the rays of special interest being in the ultra-violet part of the spectrum, and, therefore, invisible to the naked eye. For the examination of the negative so obtained a machine capable of measuring directly to the hundred-thousandth of an inch was specially constructed and applied. The pure substance itself was not used in the final investigations, the anhydrous sulphate being employed as obtained by heating the earth with strong sulphuric acid and driving off the excess of acid at red heat. For an account of the more distinctive chemical properties of the new element, the wave lengths of its distinctive rays when in a phos-

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phorescent condition, and a detailed description of the two-prism spectrograph, reference must be made to the original paper in the Royal Society's proceedings. The diagram attached to the paper exhibits the process of fractional separation, and indicates that nearly one thousand distinct operations were necessary before the element was obtained in a comparatively pure condition."

DANGER FROM ELECTRIC SPARKS.—Any machine that is likely to give off electric sparks has been considered dangerous for use in localities where those sparks might ignite explosives or gas. "The Electrical Review" tells us, however, that motors have now been constructed that are absolutely free from sparking, so that they have even been installed in a powder mill. It says: "What a holding up of the hands in horror there would have been ten years ago if anybody had suggested electric motors as the prime movers of a powder mill! Yet the art of constructing these machines has advanced so far that the induction motor is to-day considered the safest power machine for such uses. The description of the new powder factory of the United States Navy Department is of interest in showing the feeling of safety that has been engendered by the perfection of the electrical transmission and distribution of power. The induction motor has been said to be 'as simple as a grindstone.' Likewise it is as sparkless as a waterwheel, and in a dangerous place like a powder factory as safe as a block of ice." Of interest along the same lines is the conclusion of two German experts, Herr Heise and Dr. Theim, that sparking machines or motors are especially dangerous in coal mines. It would seem, however, that in the case of motors this danger need no longer be feared; that is, if the confidence of those in charge of the Government powder factory is justified.—"The Literary Digest."

ELECTRIC WELDING OF RAILS.—Mr. R. F. Danforth, Superintendent of the International Traction Company, Buffalo, N. Y., at the Ithaca meeting of the Street Railway Association of the State of New York, stated:

"The Johnson Company has taken up the process of welding girder rails into continuous lengths, in the street. Its first method

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of welding the abutting ends of rails by bringing the joint to a welding heat by the flow of an enormous current has been found to be a failure, because the homogeneity of the metal was destroyed. In the process of welding now being used in Buffalo, it has been the endeavor to follow as closely as possible the method employed in ordinary welding. After the metal is brought to a welding heat it is worked by being put under pressure of about 35 tons.

"Under the former process of electrically welding the ends of the rails together, the entire cross section of the rail had to be brought to a welding heat. In the process now in use the ball of the rail seldom reaches more than a dull red. It is believed that the quality of the steel in the rail head is not injured by this low temperature.

"In the true sense of the word, the abutting rails are not welded together, but the splice bars are welded to the web of the rail. These bars are of steel of the same quality as the rail, and measure 1 by 3 by 17 inches. The weld is made at three points, the center and ends of the bars. After the center weld is made, the ends of the bars are welded. The current flowing through the weld at five volts is about 30,000 ampères alternating. With this current flowing through the low-pressure secondary circuit, it is found necessary to cool the contacts by circulating water around them. It is found that the machine will average four joints an hour without any difficulty.

"You probably ask why we decided to use the welded joints. The reply is that we find that the welded joint not only solves the problem of maintaining a continuous rail, but also of the best return circuit. The carrying capacity of the bars as welded is greater than that of the rail itself; there is no opportunity for electrolytic action between two dissimilar metals; there are no expanded contacts to work loose and no added investment for copper. Another question frequently asked is, 'What do you do about expansion and contraction of your rail?' This is solved in two ways—first, by placing an expansion joint every 2,000 feet; second, by leaving the bolted joints at the special work.

"The cost of welded joints is not materially more than that of the bolted joint with ample bonding."

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SHIPS.

UNITED STATES.

Denver Class—Cruisers 14-19.—Bids for the construction of these six sheathed cruisers were opened at the Navy Department November 1st. It is understood that the Board on Construction recommended acceptance of bids only on the Department plans, which are for ships of 16½-knots speed and about 3,200 tons displacement, with a coal capacity of 700 tons.

The awards were made on November 27th in accordance with the above recommendation, and secured to each of the following bidders one of these vessels:

Galveston, Wm. R. Trigg Co., 24 months, $1,027,000.
Chattanooga, Lewis Nixon, 30 months, $1,039,966.
Cleveland, Bath Iron Works, 30 months, $1,041,650.
Tacoma, Union Iron Works, 27 months, $1,041,900.
Des Moines, Fore River Engine Co., 30 months, $1,065,000.
Denver, Neafie & Levy S. & E. B. Co., 30 months, $1,080,000.
Making a total for the six ships of $6,295,516.

It is to be noted that the lack of evidence of ability to complete the ships within a reasonable stated time may militate against award to the lowest bidders on naval ships. This time element has heretofore been entirely too lightly dealt with, and the rule has been to have delivery made far after the contract time has expired—sometimes a year or more—and pleas in extension, of more or less plausibility, preventing infliction of penalties. As the number of competing builders increases, and the new plants become fully equipped for fast as well as thorough work, we can hope to have ships ready for commissioning at the expiration of the contract period.

The following are the bids for the Denver class:

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I. Department Plans.

One vessel.		*Two vessels, each.*	
Townsend & Downey	$954,500	Townsend & Downey	$950,000
Wm. R. Trigg Co	1,027.000	Fore River Engine Co	1,020,000
Lewis Nixon	1,039,966	Neafie & Levy	1,050,000
Bath Iron Works	1,041,650		
Union Iron Works	1,041,900		
Fore River Engine Co	1,065,000		
Neafie & Levy	1,080,000		
Burlee Dock Co	1,105,000		
Columbian Iron Works	1,116,000		
Moran Bros. Co	1,122,000		

II. Builders' Plans.

Seventeen and one-half Knots.

One vessel.		*Two vessels, each.*	
Townsend & Downey	$1,059,500	Townsend & Downey	$1,055,000

III. *Eighteen Knots.*

One vessel.		*Two vessels, each.*	
Wm. R. Trigg Co. (Thornycroft boilers)	$1,041,000	Wm. R. Trigg Co. (Thornycroft boilers)	$993,700
Fore River Engine Co	1,065,000	Fore River Engine Co	1,020,000
Wm. R. Trigg Co. (B. & W. boilers)	1,073,000	Wm. R. Trigg Co. (B. & W. boilers)	1,024,700

IV. *Eighteen and one-half Knots.*

One vessel.		*Two vessels, each.*	
Fore River Engine Co	$1,100,000	Fore River Engine Co	$1,060,800

V. *Nineteen Knots.*

One vessel.		*Two vessels, each.*	
Wm. R. Trigg Co. (Thornycroft boilers)	$1,079,000	Wm. R. Trigg Co. (Thornycroft boilers)	$1,039,000

Kentucky.—This battleship, a sister ship to the *Kearsarge* (the trial of which is given so fully in this number of the Journal), has also completed a very successful contract trial over the Cape Ann course, the runs having been made on November 24, under good circumstances of wind and weather. The sea was fairly smooth and the tide was not strong.

The ship entered the course for the first half of the trial at 10·27·45 A. M. of the day noted, and from the beginning the machinery and boilers functioned satisfactorily.

The throttle was carried wide open from start to finish, and the first receiver took live steam from the boilers continuously during both runs.

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The oiling system operated satisfactorily, and with the arrangement of parts in this ship there is no difficulty in keeping in good and continuous touch with every journal and bearing. During a portion of the second half of the trial, which began at 12·42 P. M., the starboard feed heater gave out, presumably from split tubes, and the feed water was turned through the port heater exclusively. The feed left the hot wells at about 95 degrees Fahrenheit and entered the boilers at about 156 degrees Fahrenheit, showing a rise in temperature of some 61 degrees Fahrenheit.

During the turn between the first and second periods of the trial, from 12·25 P. M. to 12·42 P. M., the engines showed but little inclination to slow down from the rudder pressure.

Both engines ran at practically the same speed from end to end. The cut-offs were varied from .70 to .68 of the stroke, but for most of the time they were steady at .70.

No vibration at full speed could he detected in either engine room, and the absence of "panting" or apparent strain of the hull was a noticeable feature.

In all respects the engines came up to the expectations of the designers, and reflect equal credit upon the Bureau and upon the builders.

We are unable to secure the official data in time for this issue, but the reports will show that a somewhat greater power and speed were obtained than with the *Kearsarge*. The I.H.P. of main engines only was over 12,000, and, with an average of exactly 114 revolutions per minute, the speed (uncorrected) was 16⅞ knots per hour.

Dahlgren.—The contract trial of this torpedo boat took place off the Maine coast near Bath on October 27, and preliminary acceptance has been recommended. The trial was conducted on the standardized screw method, a speed-revolution curve having been established on October 23 by various runs over a measured mile, every means having been adopted by the trial board for securing the exact number of revolutions and the exact time for each run. Four double runs on the measured mile were thus made with the following results for standardization:

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		1st double run. N.	1st double run. S.	2d double run. N.	2d double run. S.	3d double run. N.	3d double run. S.	4th double run. N.	4th double run. S.
		m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.
Duration of run		2 47.75	2 40	2 26.2	2 28.2	2 17	2 11.7	2 01.4	2 01
Speed of vessel in knots per hour		21.45	22.5	24.62	24.22	26.2	27 34	29.65	29.75
Total revolutions during run by counters,	Port	650	650	647	632	638	633	637	635
	Stb'd.	650	649	646	651.5	638	631	635	633
Revs. per minure, mean		233.9	243.6	265.3	259.8	278.6	287.9	314.3	314.4
Boiler steam gage in engine room at start,	Port	197	195	198	210	200	200	208	230
	Stb'd.	195	187	200	205	195	175	200	222
Vacuum	Port	24.5	26.5	26.5	27	27	26	27	27
	Stb'd.	25	25	26	25.5	25.5	26	26	26.6

The next day, October 24, the first attempt at a full-speed run on a straight course, was abruptly brought to a close by the bursting of a tube in the forward boiler. Just prior to this a run over the measured mile had been made in exactly two minutes, or at a rate of 30 knots per hour, and with a mean engine speed of 317 revolutions per minute.

On October 27, with weather conditions less favorable than obtained on the 23d, the full-power speed trial was made, resulting in an average of 318.08 revolutions per minute, for 60 consecutive minutes corresponding to 30.0075 knots per hour.

The *Dahlgren* is 147 feet long, 146.4 tons displacement, and contracted for 30.5 knots speed. The estimated I.H.P. for this is 4,200.

She has two Normand boilers, with total grate surface of 118.7 square feet, and heating surface of 5,552.4 square feet.

The bunker capacity is 32 tons, and an endurance at 10-knot speed calculated at nearly 1,500 knots.

The engines are twin, vertical, triple-expansion $\frac{17\frac{1}{4} \times 24\frac{3}{4} \times 37}{21}$ inches.

The mean pitch of the screws was ascertained to be 11.45 feet.

During the trial the speeds of the two engines were regulated according to the varying steam pressures by shifting the links. The engines worked very smoothly, without heating of any journal. No water was used externally on any journal or wearing surface. The feed pumps worked quite satisfactorily. There was practically no vibration of the engines, either in athwartships or fore-and-aft direction; only a slight panting of the bottom was observable. The working of the engines at the highest

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speed indicated that they are well balanced, and that their framing is very stiff and their foundations strongly built. No foaming of boilers took place.

The fuel used on all the trial runs was a mixture of hand-picked Pocahontas and Kentucky Cannel coal, in the proportion of 40 pounds of Pocahontas to 35 pounds of Cannel coal, put up in bags weighing 75 pounds each.

The Cannel coal produced vast volumes of dense, black smoke, and with forced draft long sheets of dark red flame and a great quantity of burning embers issued from the chimney. Owing to the small height of the smoke pipes the smoke was driven down to the after part of the deck, making observations often very difficult.

No reliable information could be obtained of the actual amount of fuel consumed during the runs over the trial course.

During the full-power trial only four men were on duty in the engine room—two men attending to the throttle and cut-off gear of the two engines, and two men acting as oilers. The dynamo, kept running during the trial, was attended to by one of the oilers. One man on deck filled up the oil reservoirs from above. In the fire room one water tender, four firemen, two coal heavers and an additional man attending to the blower, were employed.

WEIGHT OF MACHINERY.

1. Engines, shafting, etc. (not including water), abaft forward engine-room bulkhead, pounds	90,882
2. Boilers, etc. (not including water), forward of forward engine-room bulkhead, pounds	65,797
3. Spare parts and outfit, pounds	2,193
4. Water in condensers, pumps and piping, etc., abaft forward engine-room bulkhead, pounds (442 pounds of water in scoops and stern tubes included)	5,234
5. Water in boilers, pumps and piping forward of forward engine-room bulkhead, pounds	14,711
6. Water in reserve feed tanks (⅔ capacity of tanks), pounds	8,760
Total pounds	187,577

Charleston.—The following dispatch reporting the wreck of this cruiser was received at the Navy Department on November

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14th, and was one of those startling announcements for which, since the cessation of the Spanish war, the public ear no longer listened. More recent news states that the ship has entirely disappeared, and the only consoling feature is that the casualty was not attended with loss of life:

"MANILA, *November 13, 1899.*

"SECRETARY OF THE NAVY, Washington:

"*Charleston* wrecked on uncharted coral reef, three miles northwest of Guinapak Rocks, north coast of Luzon, at 5·30 on the morning of November 2. Everybody safely landed at Kamiguin Island, armed with rifles and two Colts. The natives friendly. McDonald made Lingayen gulf in a sailing launch. When he left there was no opportunity of examining condition of wreck. Northeast monsoon and heavy sea prevailing. Reports ship struck easily, then thumped violently. Fire-room compartments flooded. First watertight doors closed promptly. Ship lies settled aft; water one foot from name; well out of water forward. Apparently very steep bank. Ten days' provisions, half rations, landed. *Helena* dispatched from Lingayen by *Oregon* to Kamiguin; due to-day.

"WATSON."

The list of officers on board the *Charleston* is as follows: Captain George W. Pigman, commanding; Lieutenant Commander John A. Norris, Lieutenant Commander W. N. Little (engineer), Lieutenant John A. Dougherty, Lieutenant Louis S. Van Duzer, Lieutenant John D. McDonald, Lieutenant (junior grade) De Witt Blamer, Ensign Ivan C. Wettengel, Ensign James B. Henry, Jr., Naval Cadet John A. Schofield, Naval Cadet Charles B. Hatch, Surgeon Charles T. Hibbett, Assistant Surgeon Edward V. Armstrong, Paymaster Z. B. Reynolds, First Lieutenant George C. Thorpe, U. S. M. C.; Boatswain Dominick Flynn, Gunner Joseph R. Ward, Carpenter John H. Gill, Acting Warrant Machinist Benjamin F. Beers, Acting Warrant Machinist Joseph Wilson, Pay Clerk R. J. Little.

The *Charleston* is one of the older vessels of the new Navy. She is included in the group of vessels following the completion of the cruisers *Chicago*, *Boston*, *Atlanta* and *Dolphin*, built in 1882

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and 1883, which were the pioneers of the present Navy. The *Charleston* was a steel protected cruiser built by the Union Iron Works at San Francisco, her keel being laid in the year 1887. The contract price of her hull and machinery was $1,017,500. She was launched in July, 1888, and placed in commission for the first time in December, 1889. The ordnance bureau of the Navy has been busy for some time past making extensive alterations in the battery of the *Charleston*, and had these been completed the ship would have been brought thoroughly up to date. She was 312 feet 7 inches long, 46 feet 2 inches beam, and 18 feet 7 inches draught, with a displacement of 3,730 tons. She had twin-screw compound engines, inclined 7 degrees 21 minutes from horizontal and rated at 6,666 I.H.P. at 18.2 knots.

She carried in her main battery six 6-inch guns and two 8-inch guns. Her secondary battery consisted of four 6-pounders, two 3-pounders, two 1-pounders, four 37-millimeter guns, two machine guns and two field pieces. Her complement for a crew was 300 men. She had also four torpedo tubes, and was rigged with two masts, each of which carried a military top. She had one funnel, and her normal coal capacity was 328 tons, and she could run 805 knots at her maximum speed. She could carry 800 tons of coal and steam 2,012 knots at her maximum speed, or 7,476 knots at a 10-knot rate.

U. S. S. Alabama.—The preliminary builder's trial of the U. S. battleship *Alabama*, constructed by the Cramps, was held in September last, and a statement made that she maintained an average speed in excess of 17 knots. The vessel is incomplete, as the side armor of Harveyized nickel-steel is not yet in place. The regular contract trial has been delayed, owing to labor strike at the Cramps, and no data of importance can be obtained regarding actual performance until this trial does take place. The *Alabama* was authorized by Act of Congress passed in June, 1896, which also called into being the battleship *Illinois*, building at Newport News, Va., and the battleship *Wisconsin*, building at the Union Iron Works, San Francisco. She is practically ready for service, with the important exception of her armor, the delay in this being caused by the armor-plate dispute.

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Launch of the Shubrick.—That a torpedo boat should be built in the City of Richmond, Va., and launched into the James is not of itself remarkable, but those persons who, on October 31, witnessed the launching of the *Shubrick* at the works of the Wm. R. Trigg Co., can safely say that the occasion was second to none as regards the eminence of the principal participators, the enthusiasm of the local populace and the completeness of the arrangements for the event. Indeed, no battleship was ever launched with greater éclat or success.

The President of the United States with the members of his Cabinet was the official and social feature of the day, and the welcome accorded the Chief Magistrate was highly complimentary and delightful. Mayor Taylor, of the City of Richmond, and Governor Tyler and former Governor Fitzhugh Lee, of the State of Virginia, were additional stars in the gathering, while the Navy was represented not only by Secretary Long, but by a number of officers, headed by Rear Admiral Melville.

Colonel Triggs' profusive liberality in providing for his host of guests was everywhere in evidence, and the Naval contingent was especially fortunate in being under the wing of Lieutenant W. Strothers Smith, U. S. Navy, inspector of the *Shubrick*. Lieutenant Smith represented Colonel Trigg in taking charge of the arrangements for their comfort, and it is to his genial personality and energetic efforts that the faultless consummation of this part of the programme is due.

The launch was a *side* launch, not common with our Naval vessels, but here, in every way, a successful and picturesque one.

The President made a very felicitous speech, followed by the other most prominent personages, and at four o'clock the little vessel was launched, being christened by Miss Carrie Shubrick, the young granddaughter of Commodore Shubrick, for whom the boat was named.

The *Shubrick* is of the following dimensions: Length, 175 feet; beam, 17 feet; draught, 4 feet 8 inches; displacement on trial, 165 tons; speed expected on trial, 26 knots. The engines are vertical, four-cylinder triple-expansion type of the following size: Diameter of H.P. cylinder, 14 inches; diameter of I.P. cylinder,

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22 inches; diameter each L.P. cylinder, 25½ inches; stroke of engine, 18 inches. She will have three Thornycroft boilers with total grate area of 136.8 square feet; heating surface, 7,548 square feet. The indicated I.H.P. at 350 revolutions per minute is calculated at 3,000, the boiler pressure being 250 pounds per square inch.

The bunker capacity is about 70 tons. She will be lighted throughout by electricity and furnished with one searchlight of an approved pattern. There will be two conning towers, the forward one to be of one-half inch nickel-steel plates.

The battery will be composed of three rapid-firing guns and mounts, weighing about two tons, with three and a half tons of ammunition. There will be mounted on deck, in approved positions, three 15-foot torpedo tubes, with torpedoes and storage space below for two additional torpedoes and five war heads. All ordnance weights will amount in total to about thirteen tons.

Berthing space will be provided for a crew of twenty-six men and three officers and provision space for twenty days. The con-contract price for the *Shubrick* is $129,750.

The Holland Submarine Boat was tested on November 7 by the Board of Survey and Inspection of the U. S. Navy Department, Rear Admiral Frederick Rogers, chairman. The test was made off Greenport, L. I., in water 20 feet deep. The run of one measured mile, submerged 10 feet below the surface, was made in 9 minutes; the *Holland* then rose, discharged a Whitehead torpedo and disappeared in 10 seconds. The torpedo weighed 840 pounds, and was discharged from the bow tube, and at a range of 400 feet it passed within 25 feet of the target flag; the torpedo had no war head and traveled 800 feet. The *Holland* then turned under water in one and a half times her own length, of 54 feet. With decks awash and against a strong ebb tide she made 8 knots speed. The Board expressed itself, unofficially, as surprised and delighted with the success of the trial in all requirements. The *Holland* was built in 1896 at the Nixon shipyard, and cost about $300,000; but she could be duplicated for about half that sum. She is 54 feet long, cylindrical in cross-section, and 9 feet in diameter amidships. It is the sixth boat

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built by Mr. John P. Holland, and the present craft will be taken to Washington in a few days for further inspection. She will make the trip through the Raritan Canal, and be lightened to 8 feet by pontoons.

Alphabetical List of Vessels of the United States Navy, December 1, 1899.

Name.	*Type.*	*Displacement, tons.*	*Present station or condition.*
Aberenda	Collier	4,670,	Samoan Islands.
Accomac	Tug	187,	Havana.
Active	Tug	296,	Mare Island.
Adams	Cruiser, wood	1,400,	Training Ship. Pacific.
Aileen	Yacht,	192,	Naval Reserve, New York.
Alabama	Battleship	11,525,	Cramps. Nearly completed.
Albany	Protected Cr	3,437,	England. Nearly completed.
Albay	Gunboat	100,	Asiatic Station.
Alert	Cruiser	1,020,	Out commiss'n. Mare Island.
Alexander	Collier	6,181,	Asiatic Station.
Alice	Tug	356,	Out commission. Norfolk.
Alliance	Cruiser, wood	1,375,	Training ship.
Alvarado	Gunboat	108,	Out commiss'n. Portsmouth.
Amphitrite	Monitor	3,990,	New York.
Annapolis	Gunboat	1,000,	Out commission. Annapolis.
Apache	Tug	650,	Norfolk.
Arethusa	Tank steamer	6,000,	Out commiss'n. Mare Island.
Arkansas	Monitor	3,235,	Bldg. Newport News.
Atlanta	Protected Cr	3,000,	Repairing. New York.
Badger	Auxiliary Cr	4,784,	Out commiss'n. Mare Island.
Bagley	Torpedo boat	167,	Bldg. Bath Iron Works.
Bailey	Torpedo boat	250,	Bldg. Gas Eng. & Power Co.
Bainbridge	T-B. destroyer	420,	Bldg. Neafie & Levy Works.
Balanga	———	——,	Asiatic Station.
Baltimore	Protected Cr	4,403,	Asiatic Station.
Bancroft	Gunboat	839,	Out commission. Boston.
Barcelo	Torpedo boat	——,	Asiatic Station.
Barney	Torpedo boat	167,	Bldg. Bath Iron Works.
Barry	T-B. destroyer	420,	Bldg. Neafie & Levy Works.
Belusan	Gunboat	——,	Repairing. Asiatic Station.
Bennington	Gunboat	1,710,	Asiatic Station.
Biddle	Torpedo boat	167,	Bldg. Bath Iron Works.
Blakely	Torpedo boat	165,	Bldg. Bath Iron Works.
Boston	Protected Cr	3,000,	Out commiss'n. Mare Island.
Brooklyn	Armored Cr	9,215,	En route to Asiatic Station.
Brutus	Collier	5,800,	Guam.

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Name.	*Type.*	*Displacement, tons.*	*Present station or condition.*
Buffalo	Auxiliary Cr.	6,000,	Out commission. New York.
Caesar	Collier	5,016,	San Juan.
California	Armored Cr.	12,000,	Contract not yet awarded.
Callao	Gunboat	246,	Asiatic Station.
Canonicus	Monitor	2,108,	Laid up. League Island.
Cassius	Collier	7,000,	Out commission. Norfolk.
Castine	Gunboat	1,177,	Asiatic Station.
Catskill	Monitor	1,875,	Laid up. League Island.
Celtic	Supply ship	6,428,	Asiatic Station.
Charleston	Protected Cr.	3,730,	Wrecked in Philippines.
Chattanooga	Protected Cr.	3,200,	Bldg. Crescent Shipyard.
Chauncey	T-B. destroyer	420,	Bldg. Neafie & Levy Works.
Chesapeake	Training ship	1,175,	Boston. Nearly completed.
Cheyenne	Tug	220,	Out commission. Port Royal.
Chicago	Protected Cr.	4,500,	S. Atlantic Station. En route.
Chickasaw	Tug	140,	Out commission. Port Royal.
Choctaw	Tug	200,	Newport, R. I.
Cincinnati	Protected Cr.	3,200,	Out commission. New York.
Cleveland	Protected Cr.	3,200,	Bldg. Bath Iron Works.
Columbia	Protected Cr.	7,375,	Out comm'n. League Island.
Concord	Gunboat	1,710,	Asiatic Station.
Connecticut	Monitor	3,235,	Bldg. Bath Iron Works.
Constellation	Sailing ship	1,186,	Training ship. Newport.
Constitution	Sailing ship	2,241,	Out commission. Boston.
T. A. M. Craven	Torpedo boat	146.4,	Bldg. Bath Iron Works.
Culgoa	Supply ship	4,500,	Asiatic Station.
Cushing	Torpedo boat	105,	Out commission. New York.
Dahlgren	Torpedo boat	146.4,	Bldg. Bath Iron Works.
Davis	Torpedo boat	132,	Out comm'n. Mare Island.
Dale	T-B. destroyer	420,	Bldg. Wm. R. Trigg Co.
Dale	Sailing ship	675,	Naval Militia, Maryland.
Decatur	T-B. destroyer	420,	Bldg. Wm. R. Trigg Co.
DeLong	Torpedo boat	165,	Bldg. Fore River Engine Co.
Denver	Protected Cr.	3,200,	Bldg. Neafie & Levy.
Des Moines	Protected Cr.	3,200,	Bldg. Fore River Co.
Detroit	Unprotected Cr.,	2,089,	North Atlantic Station.
Dixie	Auxiliary Cr.	6,145,	League Island.
Dolphin	Despatch boat	1,486,	Special duty.
Don Juan de Austria,	Gunboat	1,159,	Asiatic Station.
Dorothea	Yacht	594,	Out commission. Norfolk.
DuPont	Torpedo boat	165,	Newport.
Eagle	Yacht	434,	North Atlantic Station.
El Cano	Gunboat	560,	Repairing. Asiatic Station.
Elfrida	Yacht	173,	Port Royal.
Enterprise	Cruiser, wood	1,375,	Training ship, State of Mass.

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Name.	*Type.*	*Displacement, tons.*	*Present station or condition.*
Ericsson	Torpedo boat	120,	Out commission. New York.
Essex	Cruiser, wood	1,375,	Training ship.
Farragut	Torpedo boat	273,	Mare Island.
Fern	Tug	340,	Naval Militia, Washington.
Florida	Monitor	3,235,	Bldg. Lewis Nixon's Works.
Foote	Torpedo boat	142,	Out commission. New York.
Fortune	Tug	450,	Repairing. Norfolk.
Fox	Torpedo boat	132,	Mare Island.
Franklin	Frigate, wood	5,170,	Receiving ship. Norfolk.
Frolic	Yacht	607,	Out commission. Norfolk.
Galveston	Protected Cr.	3,200,	Bldg. Wm. R. Trigg Co.
Georgia	Battleship	13,500,	Contract not yet awarded.
Glacier	Refrigerat'g shp.	—— ,	Asiatic Station.
Gloucester	Yacht	786,	Out commission. Annapolis.
Goldsborough	Torpedo boat	247.5,	Wolf & Zwicker. Nearly com.
Guardoqui	Gunboat	42,	Asiatic Station.
Gwin	Torpedo boat	45.78,	North Atlantic Station.
Hannibal	Collier	4,291,	Out commission. Norfolk.
Hartford	Cruiser, wood	2,790,	Mare Island.
Hawk	Yacht	375,	Out commission. Norfolk.
Helena	Gunboat	1,392,	Asiatic Station.
Hercules	Tug	198,	Port Royal.
Hist	Yacht	770,	Norfolk.
Hopkins	T-B. destroyer	408,	Bldg. Harlan & Hollingsworth.
Hornet	Yacht	425,	Naval Militia, North Carolina.
Hull	T-B. destroyer	408,	Bldg. Harlan & Hollingsworth.
Huntress	Yacht	82,	Naval Militia, New Jersey.
Illinois	Battleship	11,525,	Bldg. Newport News.
Inca	Yacht	—— ,	Naval Militia, Massachusetts.
Independence	Sailing ship	3,270,	Receiving ship. Mare Island.
Indiana	Battleship	10,810,	North Atlantic Station.
Iona	Launch	—— ,	Asiatic Station.
Iowa	Battleship	11,340,	San Francisco.
Iris	Distilling ship	6,100,	Asiatic Station.
Iroquois	Cruiser	1,575,	Marine Hospital Service.
Iroquois	Tug	702,	Honolulu.
Isla de Cuba	Gunboat	1,130,	Asiatic Station.
Isla de Luzon	Gunboat	1,130,	Asiatic Station.
Iwana	Tug	192,	Boston.
Jamestown	Sail. ship, wood,	1,150,	Marine Hospital Service.
Jason	Monitor	1,875,	Laid up. League Island.
Justin	Collier	3,300,	Out commission. Mare Island.
Kanawha	Yacht	175,	Naval Militia, Rhode Island.
Katahdin	Ram	2,155,	Out commission. League Island.
Kearsarge	Battleship	11,525,	Not completed. Newport News.

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Name.	*Type.*	*Displacement, tons.*	*Present station or condition.*
Kentucky	Battleship	11,525,	Not completed. Newport News.
Lancaster	Cruiser, wood	3,250,	Gunnery training ship.
Lawrence	T-B. destroyer	400,	Bldg. Fore River Engine Co.
Lebanon	Collier	3,375,	Out commission. League Island.
Lehigh	Monitor	1,875,	Laid up. League Island.
Leonidas	Collier	4,242,	Out commission. League Island.
Leyden	Tug	450,	Newport, R. I.
Leyte	Gunboat	150,	Asiatic Station.
Machias	Gunboat	1,177,	North Atlantic Station.
Macdonough	T-B. destroyer	400,	Bldg. Fore River Engine Co.
Mackenzie	Torpedo boat	65,	Newport, R. I.
Mahopac	Monitor	2,100,	Laid up. League Island.
Maine	Battleship	12,500,	Bldg. Cramps.
Manhattan	Monitor	2,100,	Laid up. League Island.
Manila	Transport	1,900,	Asiatic Station.
Manileno	Gunboat	142,	Asiatic Station.
Manly	Torpedo boat	——,	Out commission. Annapolis.
Marblehead	Unprotected Cr.,	2,037,	Pacific Station.
Marcellus	Collier	——,	Out commission. New York.
Marietta	Gunboat	1,000,	Asiatic Station.
Marion	Wooden vessel	1,900,	Naval Militia, California.
Mariveles	Gunboat	142,	Asiatic Station.
Massachusetts	Battleship	10,810,	North Atlantic Station.
Massasoit	Tug	202,	Naval Station, Key West.
Mayflower	Yacht	2,690,	Out commission. New York.
McKee	Torpedo boat	65,	Out commission. New York.
Miantonomoh	Monitor	3,990,	Out commission. League Island.
Michigan	Iron Cr.	685,	On the Great Lakes.
Mindanao	Gunboat	83,	Asiatic Station.
Mindoro	Gunboat	142,	Asiatic Station.
Minneapolis	Protected Cr.	7,375,	Out commission. League Island.
Minnesota	Cruiser, wood	4,700,	Out commission. Boston.
Missouri	Battleship	12,500,	Bldg. Newport News.
Modoc	Tug	241,	League Island.
Mohawk	Tug	420,	League Island.
Mohican	Cruiser, wood	1,900,	Training ship. Mare Island.
Monadnock	Monitor	3,990,	Asiatic Station.
Monocacy	Unprotected Cr.,	1,370,	Asiatic Station.
Monongahela	Sail. ship, wood,	2,100,	Training ship. New York.
Montauk	Monitor	1,875,	Laid up. League Island.
Monterey	Monitor	4,084,	Asiatic Station.
Montgomery	Unprotected Cr.,	2,089,	South Atlantic Station.
Morris	Torpedo boat	104.75,	Newport, R. I.
Nahant	Monitor	1,875,	Laid up. League Island.
Nanshan	Collier	——,	Asiatic Station.

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Name.	*Type.*	*Displacement, tons.*	*Present station or condition.*
Nantucket	Monitor	1,875,	Out commission. Port Royal.
Narkeeta	Tug	192,	New York.
Nashville	Gunboat	1,370,	Asiatic Station.
Nebraska	Auxiliary Cr.	12,000,	Contract not yet awarded.
Nero	Collier	4,925,	Asiatic Station.
Newark	Protected Cr.	4,098,	Asiatic Station.
New Hampshire	Sail. ship, wood,	4,150,	New York Naval Militia.
New Jersey	Battleship	13,500,	Contract not yet awarded.
New Orleans	Protected Cr.	3,437,	Asiatic Station.
Newport	Gunboat	1,000,	Out commission. Norfolk.
New York	Auxiliary Cr.	8,200,	North Atlantic Station.
Nezinscot	Tug	156,	Out commission. Norfolk.
Nicholson	Torpedo boat	174,	Bldg. Crescent Ship Yard.
Nina	Tug	357,	New York.
Nipsic	Wooden vessel	1,375,	Naval Station, Puget Sound.
O'Brien	Torpedo boat	174,	Bldg. Crescent Ship Yard.
Ohio	Battleship	12,500,	Bldg. Union Iron Works.
Olympia	Protected Cr.	5,570,	Out commission. Boston.
Omaha	Cruiser, wood	2,400,	Marine Hospital Service.
Ondina	Launch	——,	Asiatic Station.
Oneida	Yacht	150,	Out commission. Norfolk.
Oregon	Battleship	10,288,	Asiatic Station.
Osceola	Tug	571,	Out commission. Norfolk.
Pampango	Gunboat	201,	Asiatic Station.
Panay	Gunboat	142,	Asiatic Station.
Panther	Auxiliary Cr.	4,260,	Out commission. League Island.
Paragua	Gunboat	201,	Asiatic Station.
Passaic	Monitor	1,875,	Out commission. League Island.
Paul Jones	T-B. destroyer	420,	Bldg. Union Iron Works.
Pawnee	Tug	275,	New York.
Pawtucket	Tug	225,	Puget Sound Station.
Penacook	Tug	225,	Naval Station, Port Royal.
Pennsylvania	Battleship	13,500,	Contract not yet awarded.
Pensacola	Cruiser, wood	3,000,	Receiving ship. San Francisco.
Peoria	Gunboat	488,	Out commission. Boston.
Perry	T-B. destroyer	420,	Building. Union Iron Works.
Petrel	Gunboat	892,	Asiatic Station.
Petrelito	Tug	——,	Asiatic Station.
Philadelphia	Protected Cr.	4,324,	Mare Island.
Pinta	Gunboat	550,	Naval Militia. California.
Piscataqua	Tug	850,	Portsmouth.
Plunger	Submarine T-B.,	168,	Bldg. Columbian Iron Works.
Pompey	Collier	——,	Out commission. League Island.
Pontiac	Tug	400,	Laid up. Boston.
Porter	Torpedo boat	165,	North Atlantic Station.

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Name.	*Type.*	*Displacement, tons.*	*Present station or condition.*
Portsmouth	Sail. ship, wood	1,125,	Naval Militia. New Jersey.
Potomac	Tug	667,	North Atlantic Station.
Powhatan	Tug	194,	Pensacola.
Prairie	Auxiliary Cr	6,872,	Naval Reserve.
Preble	T-B. destroyer	420,	Bldg. Union Iron Works.
Princeton	Gunboat	1,000,	Asiatic Station.
Puritan	Monitor	6,060,	Out commission. Annapolis.
Rainbow	Distilling ship	6,206,	Out commission. New York.
Raleigh	Protected Cr	3,213,	Out commission. Portsmouth.
Ranger	Unprotected Cr.,	1,020,	Mare Island.
Rapido	Tug	137,	Asiatic Station.
Reina Mercedes	Unprotected Cr.,	3,090,	Out commission. Norfolk.
Resolute	Transport	4,175,	North Atlantic Station.
Restless	Yacht	——,	Out commission. New York.
Richmond	Cruiser, wood	2,700,	Receiving ship. League Island.
Rocket	Tug	187,	Boston.
Rodgers	Torpedo boat	142,	Out commission. New York.
Rowan	Torpedo boat	182,	Out commission. Puget Sound.
Samar	Gunboat	200,	Asiatic Station.
Samoset	Tug	225,	League Island.
Sandoval	Gunboat	100,	Out commission. Portsmouth.
San Francisco	Protected Cr	4,098,	Out commission. Norfolk.
Saratoga	Sail. ship, wood,	1,025,	School ship. State of Penna.
Saturn	Collier	6,220,	Out commission. Norfolk.
Scindia	Collier	7,500,	Mare Island.
Scorpion	Yacht	850,	North Atlantic Station.
Seminole	Tug	——,	Out commission. Boston.
Shearwater	Yacht	122,	Naval Militia. Pennsylvania.
Shubrick	Torpedo boat	165,	Bldg. Wm. R. Trigg Co.
Sioux	Tug	155,	Norfolk.
Siren	Yacht	315,	Out commission. Norfolk.
Solace	Hospital ship	4,700,	Asiatic Station.
Somers	Torpedo boat	145,	Out commission. New York.
Southery	Collier	3,100,	Out commission. Norfolk.
Standish	Tug	450,	Annapolis.
Sterling	Collier	5,663,	Out commission. Boston.
Stewart	T-B. destroyer	420,	Bldg. Gas Engine & Power Co.
Stiletto	Torpedo boat	31,	Newport, R. I.
St. Louis	Sail. ship, wood,	830,	Naval Militia, Pennsylvania.
St. Mary's	Sail. ship, wood,	1,025,	School Ship. New York.
Stockton	Torpedo boat	165,	Bldg. Wm. R. Trigg Co.
Stranger	Yacht	546,	Naval Militia, Louisiana.
Stringham	Torpedo boat	340,	About completed, Harlan & Hollingsworth.
Supply	Supply ship	4,670,	North Atlantic Station.

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Name.	*Type.*	*Displacement, tons.*	*Present station or condition.*
Sureste	Tug	——	Asiatic Station.
Sylph	Yacht	152	Special duty. Washington.
Sylvia	Yacht	302	Naval Militia. Maryland.
Tacoma	Protected Cr.	3,200	Bldg. Union Iron Works.
Tacoma	Tug	——	Pensacola.
Talbot	Torpedo boat	46.5	Norfolk.
Tecumseh	Tug	214	Out commission. Washington.
Terror	Monitor	3,990	Out commission. Washington.
Texas	Battleship	6,315	North Atlantic Station.
Thornton	Torpedo boat	165	Bldg. Wm. R. Trigg Company.
Tingey	Torpedo boat	165	Bldg. Col. Iron Works, Baltimore.
Topeka	Gunboat	1,700	Out commission. Boston.
Traffic	Tug	280	New York.
Triton	Tug	212	Repairing. Norfolk.
Truxtun	T-B. destroyer	433	Bldg. Maryland Steel Co.
Unadilla	Tug	345	Mare Island.
Uncas	Tug	441	San Juan, Porto Rico.
Urdaneta	Gunboat	42	Asiatic Station.
Vasco	Gunboat	42	Asiatic Station.
Vermont	Sail. ship, wood,	4,140	Receiving ship. New York.
Vesuvius	Dynamite Cr.	929	Out commission. Boston.
Vicksburg	Gunboat	1,000	Out commission. Boston.
Vigilant	Tug	300	Mare Island.
Viking	Yacht	218	Out commission. Norfolk.
Vixen	Yacht	806	Norfolk.
Waban	Tug	——	Port Royal, S. C.
Wabash	Wooden vessel	4,650	Receiving ship. Boston.
Wahneta	Tug	192	Norfolk.
Wasp	Yacht	630	Naval Militia. Florida.
West Virginia	Armored Cr.	12,000	Contract not yet awarded.
Wheeling	Gunboat	1,000	Asiatic Station.
Whipple	T-B. destroyer	433	Bldg. Maryland Steel Co.
Wilkes	Torpedo boat	165	Bldg. Gas Engine & Power Co.
Wilmington	Gunboat	1,392	South Atlantic Station.
Winslow	Torpedo boat	142	Newport, R. I.
Wisconsin	Battleship	11,525	Bldg. Union Iron Works.
Wompatuck	Tug	462	New York.
Worden	T-B. destroyer	433	Bldg. Maryland Steel Co.
Wyoming	Monitor	3,235	Bldg. Union Iron Works.
Yankee	Armored Cr.	6,000	Out commission. League Island.
Yankton	Yacht	975	North Atlantic Station.
Yantic	Wooden vessel	900	Naval Militia. Michigan.
Yorktown	Gunboat	1,710	Asiatic Station.
Yosemite	Armored Cr.	6,145	Guam.
Zafiro	Supply ship	——	Asiatic Station.

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DENMARK.

Herluf Trolle.—On Saturday, Sept. 2, there was launched from the Royal Dockyards at Copenhagen, in the presence of the King of Denmark, the Princess of Wales, and a most illustrious gathering, the new Danish warship, the *Herluf Trolle*. Her displacement is 3,470 tons, length, about 271 feet; breadth, 50 feet, and depth in water, about 16.12 feet. She will have two propellers. The engines are calculated at 4,200 indicated horsepower, and the maximum speed at 15 knots. The armament will consist of two 24-centimeter breech-loading guns from Canet, placed in the turret; four 150-millimeter rapid-firing guns, manufactured at Bofors, Sweden, and placed in the protected corners of the deckhouse; ten 57-millimeter rapid-firing guns, made in Denmark, and eight lighter guns. There are three submarine torpedo-firing appliances, one in the bows and two at the sides. The *Herluf Trolle* is built of steel, with double bottom and numerous watertight compartments; the perpendicular side armor extends from about 3 feet above the water line to the same distance below, and its thickness decreases towards the ends. The side armor ceases about 20 feet from the bows, and the ends of the side armor are connected by means of an armored bulkhead, from which an armored deck proceeds below water to the spur. The ship is fitted with armored deck and all modern appliances.

ENGLAND.

London.—This battleship was launched at Portsmouth on the 21st instant, by Lady George Hamilton. The displacement of the *London* at the time of taking the water was about 5,000 tons, including the launching ways, but when completed she will displace 15,000 tons. The new vessel is of the following dimensions: Length between perpendiculars, 400 feet; extreme breadth, 75 feet; draught forward, 26 feet 3 inches; aft, 27 feet 3 inches. Her inverted, vertical, triple-expansion engines, made by the Earle Company, of Hull, will have an indicated horsepower of 15,000; her boilers are of the Belleville type. Her speed will be 18 knots, and her coal stowage 2,040 tons. The complement of the great vessel, when she is ready for sea, will be 773 persons, ex-

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clusive of an admiral and his staff, if carried, for whom accommodation is provided.

The armament of the *London* will consist of four 12-inch, breech-loading wire guns, twelve 6-inch quick-firing guns, sixteen 12-pounder quick-firing guns, weighing 12 cwt. each, two 12-pounder quick-firing guns, weighing 8 cwt. each, for boat use, six 3-pounder quick-firing guns, and eight .45-inch Maxims. Four submerged torpedo tubes and fourteen 18-inch and five 14-inch torpedoes complete her powers of offense. The thickness of the armor plating in various parts is thus described: For 216 feet of the sides, 9 inches, tapering beyond this length towards the bow to 2 inches; on bulkheads, 12 inches, 10 inches and 9 inches; on barbettes, 12 inches, 10 inches and 6 inches; on casemates, 6 inches; on fore conning tower, 14 inches, with 8-inch communication tubes; on the after conning tower, 3 inches, with 3-inch communication tubes; on the twelve gun shields, 8 inches and 10 inches; on the roof and floor of the same, 3 inches of Harveyed nickel-steel. The following are the particulars of the protective-deck plating: Middle deck between armor bulkheads, two thicknesses of 1 inch, with an extra thickness of 1 inch on the slopes over the machinery spaces; lower deck before forward armor bulkhead, two thicknesses of 1 inch; lower deck abaft after armor bulkhead, two thicknesses of 1 inch and ½ inch respectively; main deck between armor bulkheads, two thicknesses of ½ inch.

The *London* will have two steel masts, each fitted with a military or fighting top, and with a searchlight platform on the main topmast, and a long-distance semaphore for signaling at sea will be fitted. This semaphore is about 160 feet above the level of the water line. The masts are to be provided with three derricks, two forward and one on the mainmast, and these derricks, primarily fitted for hoisting out the boats, will be of great utility when coaling. The boats include four steamboats, two 56 feet in length and two 40 feet in length, and fourteen sailing and pulling boats, ranging from a 42-foot sailing launch to a small dinghy. The two larger are capable of steaming about 13.5 knots, and are fitted with torpedo-dropping apparatus. They will also act as

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scouts whilst the parent ship is in harbor. Three independent sets of dynamos and engines are required to light the ship, work the electric-motor fans and the searchlights. Every compartment except the double bottom, etc., will be efficiently lighted by incandescent lamps.

Bulwark.—The new battleship *Bulwark*, launched at Devonport on the 18th inst., was laid down on March 20, and has thus been under construction less than seven months. During that time 5,450 tons of material have been built into her, and it is claimed by the Devonport Dockyard staff that the work has created records both in the time she has been under construction and in the weight attained for the period. One of the three ships known as the *Venerable* class, the *Bulwark*, was designed by Sir W. H. White, Assistant Controller of the Navy and Director of Navy Construction, and she has been built under the supervision of Rear Admirals H. J. Carr and T. S. Jackson, Admiral Superintendents, and Mr. H. R. Champness, the Chief Constructor at Devonport Dockyard. The main dimensions of the ship are: Length between perpendiculars, 400 feet; extreme breadth, 75 feet; draught of water, forward, 26 feet 3 inches, aft, 27 feet 3 inches; load displacement, 15,000 tons. She will be fitted with two complete sets of engines of the vertical triple-expansion type of 15,000 indicated horsepower, and is expected to attain a speed of 18 knots. The engines, which are being made by Messrs. Hawthorn, Leslie & Co., of Newcastle-on-Tyne, have cylinders 31½ inches, 51½ inches and 84½ inches in diameter, and a stroke of 51 inches. Each set, in a separate room, is to be capable of developing 7,500 horsepower, with 108 revolutions per minute. There will be twenty boilers of the Belleville type. The armament will comprise four 12-inch breech-loading guns, worked in two barbettes, twelve 6-inch quick-firing guns in casemates; sixteen 12-pounder, 12-cwt. quick-firing guns; six 3-pounder Hotchkiss quick-firing guns; one 12-pounder, 8-cwt. boat gun, one 12-pounder, 8 cwt. field gun, and eight .45-inch Maxim guns. She will also have four submerged torpedo tubes. When commissioned the vessel will have a total of 773 officers and men. The *Bulwark* and her sister ships are identical in form, dimen-

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sions and displacement with the *Formidable* class, but differ slightly in the distribution of armor protection. In the *Venerable* class the belt of side armor is carried much nearer the bow than in the *Formidable* class, while the fore armored bulkhead, which is a feature in the *Formidable* class, has been dispensed with. Despite its suggestiveness, few ships in the history of the Navy have borne the name *Bulwark*. It was not until 1861 that any ship of this name was built, this being a steam frigate launched at Chatham. The vessel now known as the *Impregnable*, training ship for boys at Devonport, bore the name for a short period. She was originally known as the *Howe*, but on the present battleship of that name being built, her name was changed to *Bulwark*, to be again changed to *Impregnable* when she was appropriated for her present service as a training ship.

Canopus.—The trials of the new first-class battleship *Canopus* have been successfully completed at Portsmouth. Her first run at one-fifth of her power was unsatisfactory, owing to the heavy consumption of coal caused by the waste of water due to leaky joints. She has now completed two more trials at one-fifth and four-fifths her power successfully, each run having been for thirty hours. The ship was on an even keel, the draught being 26 feet fore and aft; the steam in the boilers at the one-fifth-power run was 230 pounds to the square inch, and at the four-fifths trial 255 pounds; the vacuum at the one-fifth-power run was 27.2 inches starboard and 27 inches port, and during the four-fifths-power trial 26.5 inches starboard and 26.2 inches port; while the revolutions were 64.5 starboard and 63.9 port, and 100.1 starboard 99.3 port on the two runs respectively. During the one-fifth-power trial the engines developed 2,812-I.H.P., with a coal consumption for all purposes of 1.28 pounds per unit of H.P. per hour, and during the four-fifths-power run 10,454 I.H.P., with a coal consumption of 1.68 pounds for all purposes per H.P. per hour. The speed at the economical trial was not taken, but at the four-fifths-power run the patent log recorded a mean speed of 17.2 knots. At the eight hours' full-speed trial, the ship was on an even keel, drawing 26 feet; the pressure of steam in the boilers was 289 pounds; and the vacuum 25 inches star-

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board, and 25.9 inches port. The engines worked with such evenness that as the mean of the eight hours' run they each showed 108.5 revolutions a minute, with a collective I.H.P. of 13,763, being 263 H.P. over the contract. The mean air pressure was .19 inch, and the mean speed was 18.5 knots, with a coal consumption of 1.72 pounds per H.P. per hour.

Cheerful (T. B. D.).—The trials of the new torpedo-boat destroyer *Cheerful* have been accepted as satisfactory. At the coal-consumption trial the engines indicated 5,632 H.P. with a speed of 29.941 knots. The consumption of coal was 2.84 pounds per I.H.P. per hour.

H. M. S. Venerable was launched on Thursday, November 2, from the Chatham Dockyard. She is a first-class barbette battleship, exactly similar to the *London* and *Bulwark*, launched recently from Portsmouth and Devonport respectively. The particulars officially supplied are as follows:

Length between perpendiculars, 400 feet; breadth, extreme, 75 feet; draught of water, forward, 26 feet 3 inches; draught of water, aft, 27 feet 3 inches; displacement, 15,000 tons; engines, inverted, vertical, triple-expansion; boilers, twenty of the Belleville type; indicated horse-power of engines, 15,000; speed, 18 knots; maker of engines, Maudslay Son and Field; coal stowage, 2,040 tons; complement (exclusive of admiral and his staff), 773.

Armament: Four 12-inch breech-loader wire guns; twelve 6-inch quick-firers; sixteen 12-pounder, 12 cwt. quick-firers; two 12-pounder, 8 cwt. quick-firers; six 3-pounder Hotchkiss; eight .45-inch Maxims; torpedo tubes (submerged), four; torpedoes, fourteen 18-inch and five 14-inch. Armor: Gun shields, 10-inch and 8-inch; on sides, 9-inch, 7-inch, 5-inch and 3-inch; bulkheads aft, 12 inches, 10 inches, and 9 inches; casemates, 6 inches; barbettes, 12 inches, 8 inches and 6 inches; conning towers, 14 inches, 12 inches and 3 inches; communication tubes, 3 inches and 8 inches; protective plating on bows, 2-inch. Protective deck plating—main deck, from armor board to station 20*a*, two thickness of 1 inch; from station 20*a* to stem, two thicknesses of ¾-inch; middle deck, from armor board to 28½ station level, two thicknesses of ½-inch; slope at sides, between 60 and

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130, two thicknesses of 1-inch; before 60 and abaft 130, two thicknesses of ½-inch; lower deck, forward, two ½-inch thicknesses; abaft armor board, one 1-inch and one 1½-inch thickness.

The first keelplate was laid January 2, 1899; weight of hull when launched, 5,200 tons.

The Barham, cruiser, completed at Portsmouth, on the 25th ult., a series of progressive trials which were ordered to be carried out in order to compare results with later third-class cruisers, like the *Pelorus* and *Pandora*. The trials were begun on August 10 and 11, when the ship was run at her load draught of 11 feet 9 inches forward and 14 feet 9 inches aft, and they were continued on the 23d and 24th ult., at her light draught of 10 feet 6 inches forward and 14 feet 6 inches aft. In each case the result is the mean of four runs over the measured mile in Stokes Bay:

	Light Draught.	Load Draught.
Revolutions per minute,	100.1	101.2
Steam in boilers, pounds,	132	130
Indicated horsepower,	551	616
Speed in knots,	10.138	10.078
Revolutions per minute,	143.5	143.9
Steam in boilers, pounds,	138	127
Indicated horsepower,	1,701	1,899
Speed in knots,	14.266	14.164
Revolutions per minute,	177	183.5
Steam in boilers, pounds,	138	129
Indicated horsepower,	3,242	3,683
Speed in knots,	17.553	17.837
Revolutions per minute,	201.2	204.4
Steam in boilers, pounds,	138	138
Indicated horsepower,	5,008	5,410
Speed in knots,	19.512	19.585
Revolutions per minute,	210.4	202.2
Steam in boilers, pounds,	142	128
Indicated horsepower,	5,870	5,280
Speed in knots,	20.069	19.491

The vessel is at once to be brought forward for commission on the Mediterranean station.—"Engineering."

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Prometheus.—The new third-class cruiser *Prometheus* has completed her four-hours' forced-draft trial successfully, with the following results: Pressure of steam in boilers, 262.6 pounds; ditto in engine room, 249.7 pounds; air pressure, 2.58 inches; vacuum, starboard, 24 inches, port, 24.1 inches; revolutions, starboard, 225.1, port, 219.9; I.H.P., starboard, high, 1,028.0, intermediate, 1.388.1, low, 1,238.7—total, 3,654.8; port, high, 1,036.9, intermediate, 1,309.3, low, 1,276.7—total, 3,619.9; aggregate I.H.P., 7,274.7; speed, 20.8 knots. The I.H.P. was 274.7 in excess of the contract with Earle's Shipbuilding and Engineering Company.

Perseus.—The new third-class cruiser *Perseus*, built and engined by Earle's Company at Hull, has completed her four-hours' forced-draft trial successfully, with the following results: Draught of water, forward, 11 feet 6 inches, aft, 14 feet 10 inches; pressure of steam, in boilers, 265.9 pounds, in engine room, 249.9 pounds; air pressure, 2.39 inches; vacuum, starboard, 24.2 inches, port, 23.3 inches; revolutions, starboard, 214.8, port, 214.6; mean pressure, starboard, high, 102.6, intermediate, 50.4, low, 18.9; port, high, 103.3, intermediate, 51.6, low, 18.7; I.H.P., starboard, 3,523.2, port, 3,545.5—total starboard and port, 7,068.7; speed, 20 knots. The contract with Earle's Company was for 7,000 H.P.

Coquette.—The new torpedo-boat destroyer *Coquette*, built by Thornycroft & Co., has also been successful, the result being as follows: Draught of water, forward, 5 feet 11½ inches, aft, 7 feet 4½ inches; speed, 30.211 knots; steam pressure in boilers, 216 pounds per square inch; air pressure in stokehold, 2.72 inches; vacuum in condensers, starboard, 25.0, port, 24.9; revolutions per minute, starboard, 383.8, port, 388.6; mean I.H.P., starboard, 2,820, port, 3,048—total, 5,868. The contract requirements were exceeded.

Espiegle and **Fantôme.**—These two new sloops are about to be laid down at Sheerness dock yard. Length, 185 feet; displacement, 1,040 tons. They will be improved *Condor* type, and will be steel, sheathed with wood. Triple-expansion engines and water-tube boilers will be used, and the armament will be six 4-inch rapid-fire rifles, four 3-pounders, and three machine guns.

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Sheldrake Trials.—The nine 1,000-mile trials of this torpedo gunboat have been completed, and the results have been very satisfactory in regard to the performance of the Babcock & Wilcox boilers. The principal data of these trials are as follows:

Date.	Nature of trial.	Duration in hours.	Steam pressure.	I.H.P.	Air pressure.	Coal per I.H.P. all purposes.	Coal per square foot of grate.	Water per pound of coal.	Ashes per pound of coal.	Grate surface.
1899.	*Miles. I.H.P.*									
28 February..	1,000 at 1,500	69	120	1,303	.0	1.61	12.3	...	.152	189
9 March	1,000 at 1,500	68	120	1,506	.0	1.6	12.67	...	.150	189
28 March	1,000 at 1,500	70	135	1,534	.0	1.75	14.2	...	.200	189
20 April	1,000 at 1,500	68½	130	1,537	.0	1.59	15.1	...	.150	189
5 May	1,000 at 1,800	67	135	1,829	.0	1.6	15.4	...	.216	189
19 May	1,000 at 1,800	66½	140	1,838	.0	1.68	16.4	...	.220	189
15 June.....	1,000 at 2,000	59	145	2,033	.0	1.57	17.0	...	.220	189
3 July.....	1,000 at 2,000	61½	140	2,042	.0	1.56	16.8	...	.230	189
20 July.....	1,000 at 2,150	56¾	150	2,245	.0	1.63	19.4	...	.250	189
Total.....		632¾	...	...	...	...	...	...	...	...
Mean.....		...	146	1,974	...	1.63	9.85	...	.198	...

The engines of the *Sheldrake* are triple-expansion type (twin screw), and are 22 by 33 by 49 inches with 21 inches stroke.

There are four B. & W. boilers, two boilers being in the forward compartment and two in the after compartment. Each pair of boilers is placed back to back, each boiler having its own stokehold. The total heating surface of each boiler is 2,356 square feet, and the grate surface 63 square feet. The boilers are worked at 200 pounds per square inch, which is reduced by reducing valves to 150 pounds per square inch at the engines, and the steam on its way to the engines passes through separators.

Viper and Class.—These turbine-engined torpedo-boat destroyers, now being built in England, with machinery similar to the little *Turbinia*, of Mr. C. A. Parsons, are described in Brassey's "Naval Annual." The length between perpendiculars is 210 feet, extreme beam, 21 feet, and the molded depth is 12 feet 9 inches. With a draught of 5 feet 4 inches, the displacement is 320 tons. There are four propeller shafts, each fitted with two screws and operated by two separate sets of engines. On each

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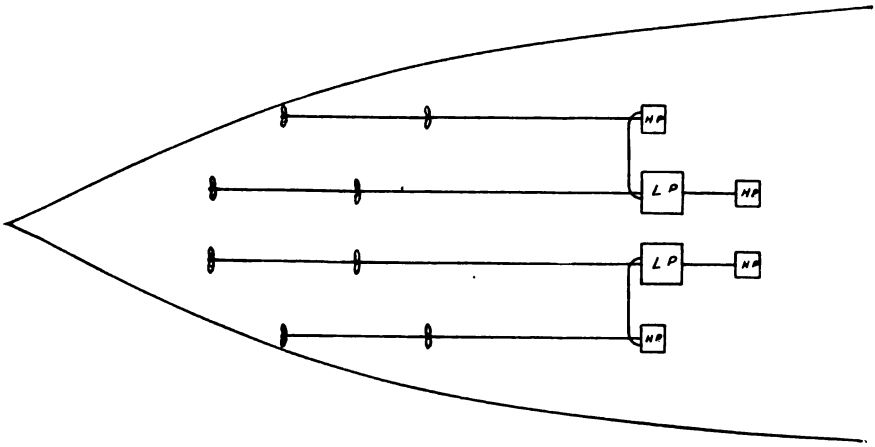
side of the vessel is a high-pressure turbine motor, driving the outer screw shaft; and on each inner screw shaft is one low-pressure motor and one small reversing turbine motor, the inner screws being used for going astern. The total power is 10,000 I.H.P., which, it is calculated, will give a speed of 35 knots, with 16 knots going astern. On each side is a surface condenser, with two air pumps driven by turbines; but the two circulating pumps are operated by ordinary double-acting engines. The boiler-room weights, with water in boilers, is 100 tons 15 cwt.; engine-



room, with auxiliary gear and water in condensers, 52 tons 6 cwt.; propellers, shafting, etc., 7 tons 14 cwt. Consequently, with 12,000 H.P. developed, the weight of machinery is about 30 pounds per I.H.P. In a 30-knot torpedo-boat destroyer of ordinary design and similar size, the corresponding machinery weights are 78 tons, 56 tons and 10 tons; or, with 6,000 H.P. developed, about 53¾ pounds per I.H.P. In the turbine engines the lowered center of gravity is also an advantage, and the machinery can be driven to the highest speed without danger.

In this connection we note the rumored great speed obtained in the recent trial of the *Viper*, but reliable data is not yet at hand upon which to base judgment regarding the possibilities of the turbine engine.

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Thistle.—The new first-class gunboat *Thistle*, built and engined by the London and Glasgow Shipbuilding Company, has completed her contract steam trials. The *Thistle* is a sister ship to the *Dwarf*, which has just completed for sea at Devonport, and the satisfactory results which the latter vessel attained on her steam trial have been eclipsed by those now attained by the *Thistle*, which has already proved herself to be a far more economical steamer than the *Dwarf*, which on her 30-hours' run under the same conditions recorded a coal consumption of 2.37 pounds.

The mean results of the 30-hours' trial were: Steam in boilers, 186 pounds, at engines, 175 pounds; vacuum, starboard, 26 inches, port, 26.5 inches; revolutions, starboard, 230.5, port, 229.5; I.H.P., starboard, 344, port, 352—total, 696. Speed, 11.5 knots; coal consumed per I.H.P. per hour, 2.13 pounds. The result of the eight-hours' natural-draft trial were equally satisfactory, and as follows: Steam in boilers, 215 pounds, at engines, 205 pounds; vacuum, starboard, 25.5 inches, port, 25.7 inches; revolutions, starboard, 254.5, port, 255; I.H.P., starboard, 475, port, 485—total, 960. Air pressure, .5-inch; speed, 13 knots; coal consumed per I.H.P. per hour, 2.15 pounds. On the four-hours' forced-draft trial the results were: Steam in boilers, 220 pounds, at engines, 200 pounds; revolutions, starboard, 280, port, 282; I.H.P., starboard, 680, port, 670—total, 1,350. Air pressure, .75-inch; coal consumed per I.H.P. per hour, 2.47 pounds; speed, 13.5 knots.—"United Service."

FRANCE.

Suffren.—This first-class battleship, which was successfully launched at Brest on 25th of last July, is hoped to be completed by July, 1901. If these dates are observed, the period of her construction will be thirty-one months, which will be less than any other French battleship hitherto built. She is also the largest battleship built by the French up to the present, her tonnage displacement being 12,728. The other dimensions are: Length, 125.5 meters (411 feet); beam, 21.36 meters (69 feet); draught, 8.4 meters (27½ feet). She will have three propellers

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driven by vertical triple-expansion engines, and water-tube boilers of a collective H.P. of 16,200, giving an estimated full speed of 18 knots. The normal coal supply will be 820 tons, which can be increased to 1,150 tons. With normal stowage her radius of action will be 5,100 at 10 knots, and 1,100 miles at full speed, and with the extra coal these distances are increased to 7,000 and 1,800 miles respectively. The hull at the water line is protected from end to end by a Harveyized steel belt with a maximum thickness of 300 millimeters (11.8 inches), extending to a height of 1.10 meters (3.6 feet) above the water line. Armor to a height of 2 meters (6.5 feet), 130 millimeters (5.1 inches) thick protects the battery for the Q.F. guns on the upper deck, which, as in the *Charlemagne* and her sisters, has the defect of leaving a considerable extent of side between the lower belt and the upper deck exposed without protection to shell fire. There is also an armored deck 70 millimeters (2.7 inches) thick at the top of the belt. The armament is entirely protected by armor, and consists of: Four 305-millimeter (12-inch) guns in pairs in the two turrets forward and aft in the midship line; ten 164-millimeter (6.4-inch) Q.F. guns, four of which are mounted in the battery and six in turrets above the battery; eight 100-millimeter (3.9-inch) guns; twenty 47-millimeter (1.8-inch) guns; two 37-millimeter (1.4-inch) guns; and four torpedo tubes, two of which are submerged. The plans of the *Suffren* are by M. Thibaudier, and her cost will be 29,492,887 francs (£1,179,715 10s.).

Infernet.—This third-class cruiser was launched from the Chantiers de la Gironde at Bordeaux on September 7. Her dimensions are as follows:

Length, 311 feet; beam, 39 feet; displacement, 2,460 tons, with a mean draught of 15 feet 6 inches. Unlike the larger number of French cruisers the, *Infernet* has nearly a straight stem, while her stern above water comes to a sharp point. There will be four groups of water-tube boilers on the Normand system, which have been constructed at the Creusot works; the boilers, eight in number, containing 8,112 tubes, will be in four stokeholds. The engines, of the usual triple-expansion type, with four cylinders, are to develop 8,500 I.H.P. under forced draft,

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which, with 175 revolutions, are to give a speed of 21 knots. The engines will be placed in separate compartments, divided by a watertight bulkhead. The armament will consist of two 140-millimeter (5.4-inch) Q.F. guns, four 100-millimeter (3.9-inch) Q.F. guns, with eight 3-pounders; the 3.9-inch guns being in sponsons on the broadside, and the 3-pounders, six on the spar-deck and two under the poop. The ship also carries fourteen automatic torpedoes, fitted with a special releasing attachment, permitting of their being discharged with great rapidity. As is their custom with small vessels, the builders have launched the ship with engines and boilers in place, so that the ship is almost in condition to make her preliminary trials, after which she will proceed to Rochefort for her official ones. She was commissioned on December 9, 1896. There are at present under construction at the same yard the first-class armored cruiser *Kléber* and torpedo boats *Nos. 239, 240* and *241*.

Admiral Gueydon.—On Wednesday, September 20, this new first-class armored cruiser was launched from the Government yard at Lorient. Her dimensions are as follows: Length, 452 feet 9 inches; beam, 63 feet 8 inches; displacement, 9,517 tons, with a draught of 24 feet 7 inches. She will have three screws, and her engines are to develop 20,000 I.H.P., giving a speed of 21 knots under forced draft. The normal stowage is 1,020 tons, but she can carry 1,600 tons. In the first case, she has a radius of action of 1,230 miles at full speed, and 6,500 miles at 10 knots. With her full coal stowage, her radius of action is 1,920 miles at full, and 10,300 at 10 knots speed. Her boilers will be of the Niclausse water-tube type. She will have a water-line belt of 6.8 inches hardened steel, tapering at the extremities to 3.5 inches, with a belt above, 3.5 inches thick, reaching to the main deck, while guns will be protected by 8-inch armor on the turrets for the two heavy ones, and 3.8-inch armor on the casemates for the secondary battery. The armament will consist of two 19.4-centimeter (7.6-inch) guns in the turrets, one forward and one aft; eight 16.4-centimeter (6.4-inch) Q.F. guns in casemates; four 10-centimeter (3.9-inch) Q.F., and sixteen 3 and 1-pounder Q.F. guns, with two submerged torpedo tubes. The ship is to be

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completed by the end of 1901, the order of her construction having been given on the 13th of August, 1897.—"Le Temps" and "Le Yacht."

Battleship Alterations.—Recently French battleships have undergone extensive alterations to lighten them by reducing the weight of the armor and of the artillery, and by abolishing part of the superstructure, removing in some cases, for instance, one of the two military masts. In reducing the weight of the artillery modern quick-firing guns have been substituted, and in altering the superstructure wood has been as much as possible dispensed with. The transformation has included the substitution of water-tube boilers for the existing ones, and in some ships a change of the engines. The *Redoubtable* has now triple-expansion engines, her 27.44-centimeter guns have been replaced by others of 24 centimeters, and the 13.86 centimeters by 10 centimeters. In the course of a few years she will be fitted with water-tube boilers. The *Devastation* has her new guns already, and will receive her new boilers in the course of a few months. The *Courbet* is about to change her guns at Brest. Her boilers are almost new, but in the course of a few years they will be replaced by water-tube boilers. The *Formidable* and the *Amiral Baudin* have already undergone a first change in their artillery by the substitution of four 16.47-centimeter guns placed in two casemates with 10-centimeter protection for one 37-centimeter gun amidships. The second change will consist of the 37-centimeter guns fore and aft being replaced by 27.44 centimeter guns of 40 caliber, in turrets. On the *Amiral Duperré* the 34-centimeter gun amidships will be exchanged for 16.47-centimeter guns placed as in the *Formidable* and *Baudin*. The four more recent vessels, the *Hoche*, *Neptune*, *Marceau* and *Magenta*, are undergoing, or will undergo, a reduction in their superstructure and a change in their boilers. The *Hoche* is receiving Belleville boilers, and Niclausse boilers will be placed in the *Marceau*. In addition to the battleships, the coast-defense ships *Requin*, *Indomptable* and *Furieux*, are to have their armor reduced and the 42-centimeter guns replaced by 27.44 centimeter. They are also to receive Niclausse boilers.

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GERMANY.

Cruiser A.—The first-class cruiser *A* will be of 394 feet in length, 44 feet 6 inches beam, 24 feet draught and 8,868 tons displacement. Her armor will consist of a belt 3.94 inches, a protective deck of from 1.97 inches to 2.75 inches, and of turrets 4 inches to 6 inches thickness. Three triple-expansion engines, of 15,000 I.H.P., will receive steam from Dürr boilers, and will give the vessel a speed of 20.5 knots. The normal coal capacity will be 950 tons. The armament, entirely composed of quick-firing guns, will consist of two 40-caliber long, 24-centimeter, in two turrets 6 inches thick; ten 15-centimeter, equally long, of which four are in 4-inch turrets and 6-inch armored casemates of equal strength; ten of 8.8-centimeter, of 30-calibers, and ten of 3.7-centimeter guns on the upper deck and the superstructures. Four 8-millimeter machine guns and four 45-centimeter torpedo tubes, of which one will be forward and two aft, in the broadside below the water line, and one aft, above the water line, will complete the armament. The cruiser will have a crew of 523 men.

Steam Trials.—The new second-class cruiser *Victoria-Louise* has completed her trials successfully, having averaged 19.1 on her run under forced draft, the stipulated contract speed for her and her sister ships being 19 knots.

Cruiser Tiger, formerly *Ersatz Wolf*, belonging to the *Iltis* class, has been launched recently in Danzig. The new gunboat has a displacement of 894 tons, engines of 1,300 I.H.P., and a speed of 13.5 knots. Coal supply will suffice for 3,000 sea miles at 10-knot speed. Armament consists of four 8.8 centimeter rapid-firing guns, six 3.7 centimeter machine guns and two machine rifles.

Cruisers Vineta and **Freya** are ready for their trials. These ships are of special interest, because of their equipment with water-tube boilers of different systems. *Freya* has Niclausse boilers, *Vineta*, as well as the *Victoria-Louise*, have Dürr boilers, and the two sister ships, *Hertha* and *Hansa*, have Belleville boilers. *Vineta* and *Hansa* have a displacement each of 5,900 tons, *Victoria-Louise*, *Hertha* and *Freya* each 5,630 tons.

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ITALY.

Agordat.—The "Escercito Italiano" states that the Italian cruiser *Agordat* was successfully launched at Castellamare di Stabia on October 12. Her length is 87.60 meters; beam, 9.32 meters; draught, forward, 3.03, aft, 4.25 meters; displacement, 1,320 tons. She has two engines of triple-expansion type, developing 7,500 horsepower, and supplied with steam by eight water-tube boilers of the Blechynden type, with a pressure of 15 atmospheres. The interior of the *Agordat* is of soft steel, wood being used as little as possible, and in many cases aluminum is substituted. She has a deck of hardened steel extending along her whole length. Her armament consists of fourteen 7.6-centimeter quick-firing guns, two machine guns and two torpedo tubes. A short time ago the *Lampo*, torpedo-boat destroyer, built for the Italian government by Messrs. Schichau, of Elbing, was launched. Her length is 60 meters, and her nominal speed under forced draft 36 knots.

JAPAN.

Idzumo.—Sir W. G. Armstrong, Whitworth & Co. launched the Japanese first-class armored cruiser *Idzumo* on the 19th September. The principal dimensions of the vessel are as follow: Length between perpendiculars, 400 feet; breadth, 68 feet 6 inches; depth, 41 feet; draught, 24 feet 3 inches; displacement, 9,750 tons. The armament consists of four 8-inch breech-loading guns, twin mounted, in barbettes; fourteen 6-inch quick-firing guns—ten in casemates, six on the main deck and four on the upper deck, the remaining four being on the upper deck, protected by shields; seventeen 12-pounder quick-firing guns—eight on the shelter decks, two on the main decks forward, four on the bulwarks and three in the military tops; four submerged torpedo tubes—two forward and two aft. The vessel has a complete waterline belt of Harveyed nickel-steel armor 7 inches thick amidships, reduced at the ends. Above this there is a citadel of 5-inch Harveyed nickel-steel armor inclosing the bases of the barbettes, and carried from the top of the waterline belt to the main deck. The barbettes are of Harveyed nickel-steel 6 inches thick; the casemates are of nickel-steel 6 inches thick,

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and the conning tower is Harveyed nickel-steel 14 inches thick. The machinery is of the twin-screw, vertical, triple-expansion type, to develop 14,500 indicated horsepower, and the speed guaranteed is 20¾ knots, the boilers being of the Belleville latest type. She has a bunker capacity for about 1,600 tons of coal. Accommodation is provided for an admiral, 52 officers and 430 petty officers and men. The vessel is a sister ship of the *Asama* and *Tokiwa*.

Shikishima.—On May 1, 1897, the first plate of the keel of this fine battleship was laid, and within twenty-nine months (notwithstanding a six-months' delay in the delivery of armor, armament and engines, due to the unfortunate engineers' strike) her trials have been completed to the entire satisfaction of all parties concerned. This probably constitutes a record in the history of battleship building, and the fact that a war vessel of some 15,000 tons displacement and 19 knots speed can be completely built, equipped, armored, armed and engined in a little over two years, speaks well for the methods and facilities of the Thames Iron Works, Shipbuilding and Engineering Company, the contractors for the vessel.

The ship having been dry-docked at Portsmouth, and her bottom having received her final coating of anti-fouling composition, on October 10 she left that port for Torbay, to run an 8-knot course in deep water. The engines worked smoothly during the whole of the time, indicating upwards of 15,000 horsepower on the measured distance, and she recorded a mean speed of 19.023 knots at slightly over her load draught of 27 feet 3 inches. She turned a complete circle in three minutes sixteen seconds, heeling only 5 degrees, her rudder being put from hard over to hard over in sixteen seconds.

The following are a few of her leading particulars:

Length over all, 438 feet; length between perpendiculars, 400 feet; breadth, extreme, 75 feet 6 inches; depth, extreme, 45 feet 2½ inches; draught, mean, 27 feet 3 inches; displacement at mean draught, 14,850 tons; indicated horsepower, (over) 15,000; number and type of boilers, 25 Belleville; heating surface, 40,000 square feet; mean speed on trial, 19.023 knots; number of screws,

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two; side armor, Harveyized nickel-steel; maximum depth, 8 feet 2 inches; maximum thickness, 9 inches; minimum thickness, 4 inches; thickness of barbette armor, 14 inches; number of incandescent 16-candlepower lamps, 800; number of 24-inch searchlights, 6; power of 24-inch searchlights, 20,000 candlepower.

The armament of the *Shikishima* consists of four 12-inch 40-caliber guns, two in each barbette; fourteen 6-inch quick-firing guns, mounted in casemates; twenty 12-pounder guns; twelve 47-millimeter quick-firing guns; four 18-inch torpedo tubes, below water line, and one similar tube above water line.

In general constructive details the *Shikishima* follows the usual methods employed for ships of this class in the British Navy. She is built on the usual bracket-frame system, with wing passages on each side, to be used for holding coal. She has a double bottom amidships, with watertight flats at the ends of the vessel, thus having practically a double bottom from end to end. The armor is of Harveyized nickel-steel. The side protection consists of a belt which extends from stem to stern. The belt is 8 feet 2 inches in maximum depth. It is 9 inches thick amidships, and tapers to 4 inches thick at the ends. It has a vertical extension of 5 feet 6 inches below the water line, and 2 feet 8 inches above, at the designed load draught.

Above this belt, and carried to the height of the main deck, there is side armor 6 inches thick for a length of 250 feet, with screen bulkheads at ends also 6 inches thick, forming a complete armored citadel, extending longitudinally over the space between the two barbettes. Between the armor deck and the belt deck there are 12-inch screen bulkheads, which join the barbettes to the side armor. The armored deck is arranged according to the modern principle, as in the ships of the *Canopus* class, its sides being joined to the lower edges of the belt. It has sufficient curve to rise 2 feet 8 inches above the water line amidships. From stem to stern it is 2 inches thick, but an extra plate of 1½ inches thick is worked on the slope of this deck within the citadel, so that in this part the total thickness of the deck is 3½ inches.

Yakumo.—The principal dimensions of this first-class armored

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cruiser, which was launched from the Vulcan Company's yard at Stettin, last July, are as follows: Length, 407 feet 9 inches; beam, 64 feet 4 inches; mean draught, 23 feet 9 inches, with a displacement of 9,850 tons. The boilers will be water-tube, of the Belleville type, and her engines are to develop 11,200 I.H.P. under natural draft, giving a speed of 18 knots, and 16,000 I.H.P. under forced draft, giving a speed of 20 knots. Her normal coal supply will be 600 tons, giving a radius of action of 5,000 miles at 10 knots, but 1,100 tons can be carried when necessary, which will give a radius of action of nearly 10,000 miles at economical speed. Protection will be afforded by a complete armor water-line belt of hardened steel, with a maximum thickness of 7 inches, tapering to 3.5 inches at the extremities, while the armor on the two turrets for the heavy guns and the casemates for the 6-inch Q.F. guns will be of 6-inch steel, also hardened by the Krupp process, and the armored deck, 2.5-inch steel. Her armament, which is to be supplied by the Elswick firm, will consist of four 8-inch Q.F. guns, two in each turret, one forward and one aft; six 6-inch Q.F. guns in casemates; twelve 12-pounder and seven 2.5-pounder Q.F. guns, with five torpedo-tubes, one above water in the stem and the other four submerged.

RUSSIA.

Pallada.—This new second-class cruiser, built at the Franco-Russian Works, on Galernii Island, St. Petersburg, was launched on the 20th September, in presence of the Tsar, Tsaritsa, and other distinguished personages.

Her dimensions are as follows: Length, 406 feet; beam, 55 feet; displacement, 6,630 tons, with a mean draught of 21 feet. The armament will consist of eight 45-caliber 6-inch Q. F. guns, twenty 3-inch 12-pounder Q.F. guns, and eight smaller Q.F. guns. It was originally intended to give this ship and her four sisters six 4.7-inch Q.F. guns, but the authorities seem to have decided in favor of a larger battery of 12-pounders. The engines are to develop 16,000 I.H.P., giving an estimated sea speed of 19 knots. There will be three screws, and steam will be provided by twenty-four Belleville water-tube boilers. There is an armored

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deck 1.5 inches thick on the flat and 2.5 inches thick on the slopes, while coal bunkers are situated immediately above and below the slopes of the armored deck. Great care has been taken to avoid the use of wood, the bed places in the cabins even being of steel.

Variag.—The Russian cruiser *Variag*, constructed by the Messrs. Cramps, of Philadelphia, was successfully launched from the yards of the builders on October 31. The ceremony of the Russian Orthodox Church was performed as the vessel glided into the stream. As the ship moved down the ways, the Rev. Hotovitsky, gowned in yellow robes, read from the Greek Testament and recited a chant, in which the Russian officers and sailors joined. A large gilded cross was waved before the bow, and holy water sprinkled on it. The contract requires that the *Variag* make a speed of 23 knots an hour for twelve hours. No date has yet been set for the trial trip.

Borodino.—The "Kronstadtski Vicstnik" publishes some particulars of the Russian battleship *Borodino*, building at the docks of the New Admiralty, St. Petersburg. The length of the vessel is 397 feet; beam, 76 feet; draught on an even keel, 26 feet; displacement, 13,600 tons. Her engines will develop 16,000 horse-power. Like the *Tsarevitch*, building in France, she will have a special protection, $1\frac{9}{16}$ inches thick, against torpedoes. Her belt of armor will be 7 inches thick in the upper part, 9 inches in the middle, and 4 inches in the lower part.

SWEDEN.

The Swedish government are at present adding to their navy two 20-knot cruisers, the *Clas Uggla* and the *Psilander*. These are being built at the Bergsund Works, Stockholm, the machinery being constructed at Motala. Also the battleship *Dristigheten* is being constructed at Lindholm, Gothenburg. The Swedish Board of Admiralty have selected the Yarrow type of water-tube boiler for these vessels.

Dristigheten.—Towards the end of last year the first keel plate of the new coast-defence battleship *Dristigheten* was laid at the Lindholm yard at Gothenburg, for the Swedish Navy. She is slightly larger than her predecessors, the *Thor* and *Njord*,

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which were both launched last year from the same yard. Her dimensions are as follows: Length, 285 feet 6 inches; beam, 49 feet 3 inches; displacement, 3,500 tons, with a mean draught of 16 feet. The engines are to develop 5,000 I.H.P., giving a speed of 16 knots; the boilers, which are of the Yarrow water-tube type, are being constructed at the Motala Engine Works. Protection is afforded by a complete water-line belt of nickel-steel 8 inches thick, but tapering to 4 inches at the extremities; the conning tower is similarly protected, while the armor on the turrets for the heavy guns is 8 inches in front, tapering to 6 inches in rear, while the casemates for the secondary battery are of 5-inch steel. All the armor is being made by the French firm of St. Chamond.

The armament will consist of two 21-centimeter (8.2-inch) guns, one forward and one aft in turrets, and six 15-centimeter (5.9-inch) Q.F. guns in a central battery amidships, with ten 5.7-centimeter (2.2-inch) and four 3.7-centimeter (1.4-inch) smaller Q.F. guns, and two submerged torpedo tubes for 18-inch torpedoes on the broadside. All the guns are being made at the Bofors Works.

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MERCHANT STEAMERS.

Twenty-five New Steel Ships.—At prices now prevailing for vessel property on the Great Lakes the value of twenty-five steel vessels under contract with the American Shipbuilding Co. and three independent yards, is $7,637,000. An estimate made a short time ago referred only to vessels being built by the consolidated ship yards, and the total value was based on contract prices. These twenty-five vessels, with one exception, are freight carriers, and all are to come out in 1900. A couple of steamers to be completed this fall—one at Detroit and the other at Toledo—are not included. Neither does the list include wooden vessels, although James Davidson, of West Bay City, Mich., has one very large wooden vessel on the stocks, and will probably build two more to come out in 1900. Of the twenty-four steel freighters only four are tow barges. In a single trip this fleet will carry 150,200 gross tons, and in a full season just about 3,000,000 gross tons, but its capacity for 1900 will probably not reach much more than half the latter figure, on account of delays that will be encountered in the ship yard. Some of the vessels will not be out until very late next fall. The list follows:

BUILDING BY AMERICAN SHIPBUILDING CO. FOR:	Approximate value at present prices.	Estimated capacity, gross tons in one trip.
A. B. Wolvin and American Steel and Wire interests, four 500-foot steamers	$1,550,000	32,000
A. B. Wolvin and others, two Welland-Canal size steamers	345,000	6,000
Carnegie-Oliver steel interest, six steamers	2,280,000	44,500
Bessemer Steamship Co., one steamer and two tow barges	775,000	21,000
Eddy Bros. of West Bay City, two steamers	680,000	12,100
John Mitchell of Cleveland, one steamer	350,000	6,100
Minnesota Steamship Co., two tow barges	450,000	14,400
Robert R. Rhodes, Cleveland, one Welland-Canal size steamer	172,000	3,000
Detroit and St. Clair River Excursion Company, a passenger steamer	300,000	.....

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BUILDING BY UNION DRY DOCK CO. OF BUFFALO FOR:	Approximate value at present prices.	Estimated capacity, gross tons in one trip.
Lehigh Valley Trans. Co., one package freighter.....	395,000	5,100
BUILDING BY CRAIG SHIPBUILDING CO. OF TOLEDO FOR:		
Arthur Hawgood and others of Cleveland, one Welland-Canal size steamer	170,000	3,000
BUILDING BY JENKS SHIPBUILDING CO. OF PORT HURON FOR:		
Account of sale, one Welland-Canal size steamer.....	170,000	3,000
	$7,637,000	150,200

Oceanic.—We are able to add here to the machinery data published in May number of the JOURNAL (page 262), of this latest of the large steamers of the Oceanic Steam Navigation Company, repeating some items in order to assemble the principal dimensions.

Engines.—Four-cylinder, triple-expansion, inverted, vertical type, with cylinder diameters of high pressure, 47.5 inches; intermediate pressure, 79 inches; low pressure (2), 93 inches, with a common stroke of 72 inches. Piston valves are used on the high and intermediate cylinders, and double-ported slide valves on the low pressure. Indicated horsepower is 28,000.

The ship has twin screws, and the propellers being made of Manganese bronze, and are 22 feet 3 inches in diameter.

The condensers are of the independent, cylindrical type, but the air pump is driven from the low-pressure crossheads of main engines.

The shafting is hollow, and crank shaft is 25 inches diameter, with crank pins 26 inches diameter.

Boilers.—There are fifteen double-ended, cylindrical, Scotch boilers, as follows:

Three of 16 feet 6 inches diameter; ten of 15 feet 3 inches diameter; two of 14 feet 10 inches diameter, each being 18 feet 6 inches long.

The first named three have four furnaces at each end, while the remaining twelve have but three furnaces at each end, making a total of ninety-six furnaces. The length of the grate is 5 feet

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9 inches in all furnaces, while the width varies but slightly, being 3 feet 4 inches in the three largest boilers, 3 feet 7 inches in the ten intermediate boilers, and 3 feet 6 inches in the two smallest boilers, the largest boilers having less width of grate, owing to having four furnaces at each end.

Aggregate grate surface is 1,937.75 square feet, while the total heating surface is 73,966 square feet.

A steam pressure of 192 pounds per square inch is carried, but the boilers have been tested to 400 pounds per square inch.

The average daily consumption of coal is about 400 tons, per day, but accurate log data of engine speed and ship speed are not yet available.

Ivernia.—The successful launching of the Cunard Line steamship *Ivernia* from beneath one of the large sheds of the shipbuilders, Messrs. C. S. Swan and Hunter, Limited, Wallsend-on-Tyne, on September 21, was a "red letter" event for the North-East Coast, and was witnessed by many of the leading shipbuilding experts of the district. With one exception, that of the White Star Liner *Oceanic*, the *Ivernia* is the largest vessel at present afloat that has been built in the United Kingdom, the *Great Eastern* necessarily being excepted. There are other two larger vessels built in Germany, and it will be interesting to contrast the gross register tonnage of these four largest vessels afloat.

The *Oceanic* is 17,274 tons.

The *Deutschland* is 15,500 tons.

The *Kaiser-Wilhelm der Grosse* is 14,349 tons.

The *Ivernia* is about 13,900 tons.

The keel was laid on December 6th of last year, and considering the difficulty they have had to contend with owing to the scarcity of men and the short time that the men obtainable are working, the work has been done very expeditiously. It is expected that the *Ivernia* will take up her station on the Liverpool and Boston service early next year.

The *Ivernia* is intended for the company's line between Liverpool and Boston, and is designed mainly for the carriage of cargo, third-class passengers and cattle, although a few first and sec-

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ond-class passengers will be carried, about 150 of the former and about 200 of the latter. Of third-class passengers she will carry about 1,000; 500 of these are accommodated in two, four and six-berthed state rooms. Stalls will be fitted for about 800 head of cattle and 80 horses.

The leading particulars of the vessel are: Length over all, 600 feet; length between perpendiculars, 580 feet; beam, extreme, 64 feet 6 inches; depth molded to upper deck, 41 feet 6 inches; depth molded to shelter deck, 49 feet 6 inches; gross tonnage, about 13,900 tons; speed on trial, 16¼ knots. There are four complete steel decks—lower, main, upper and shelter; and a steel orlop deck from the boiler-room forward to the stem, and a bridge deck 280 feet long above the shelter deck. The space between the orlop and lower decks forward is insulated for carrying chilled beef, three large refrigerating engines being fitted in a house on the upper deck, and also a smaller one for the ship's own stores.

The engines are of the quadruple-expansion type, the diameters of the cylinders being 28½, 41, 58½ and 84 inches respectively for the high, first intermediate, second intermediate and low pressure, with a stroke of 54 inches. The arrangement of cylinders from the forward end is somewhat unusual—high pressure, low pressure, first intermediate, second intermediate. Each cylinder, which has two bodies, and also double covers, is carried on two cast-iron columns of box form with separate faces, and the usual pumps are worked from the crossheads, the condenser being behind. The soleplate is of cast iron, and, like the columns, very massive. This is the more interesting as the Wallsend Company make all their own castings. All the shafting is of steel, forged by hydraulic pressure when the metal is in the fluid condition, as carried out at Whitworth's works. The propellers are three-bladed and of Manganese bronze, with cast-iron bosses. There are nine boilers, all single-ended. They are to work at 210 pounds pressure. They will all go into one boiler room, six being placed back to back in double rows across the ship, with three boilers at the after end, so that there will be three rows and two stoking platforms, from one of which six boilers will be fired, and from the other only three will be fired. There is a separate

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donkey boiler. There will only be one funnel, but it will be 140 feet high from the keel, and it is 15 feet in diameter. The steam pipes are of wrought iron, lap welded, with expansion joints. They and much of the auxiliary machinery came from Glasgow.

Islanda.—Messrs. Sir Raylton Dixon & Co. (Ltd.) launched on October 7th the steamer *Islanda*, built to the order of Messrs. British India Steam Navigation Company, of London, for their Eastern trade. The principal dimensions are: Length, 424 feet 6 inches; breadth, 50 feet 8½ inches; depth, 32 feet, and the deadweight carrying capacity about 8,000 tons. The principal decks are of steel and iron, the upper deck being sheathed with teak. The water ballast will be carried in a cellular double bottom all fore and aft, also in fore and aft peaks, and large deep tanks in No. 3 hold. Triple-expansion engines will be fitted by Messrs. T. Richardson & Sons (Ltd.), Hartlepool, having cylinders 26½ inches, 42 inches, 66½ inches, by 51 inches stroke, supplied with steam by large single-ended boilers working at 160 pounds pressure, fitted with Howden's system of forced draft.

Trent.—Messrs. Robert Napier & Sons, Limited, Govan, launched on the 19th September, the *Trent*, the second of two steel screw steamers which they have on hand for the Royal Mail Steam Packet Company, London. The general dimensions are: Length, 425 feet; breadth, 50 feet; depth, 35 feet; gross tonnage, about 5,500. Accommodation has been provided for a large number of first-class passengers. The machinery consists of a set of triple-expansion engines of 7,000 indicated horsepower, with six single-ended steel boilers for a working pressure of 180 pounds, with Howden's system of forced draft.—"Engineering."

Granada.—Messrs. John Priestman & Co., Southwick, launched on September 9th the screw steamer *Granada*, built to the order of Messrs. A. C. de Feritas & Co., of Hamburg, for the Argentine and Canadian cattle trade. The principal dimensions are: Length, 410 feet; breadth, extreme, 52 feet 2 inches; depth molded to shelter deck, 38 feet 7 inches; having a total displacement of about 11,000 tons. The engines and boilers

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will be supplied by Messrs. T. Richardson & Sons, Limited, West Hartlepool. The cylinders are 27 inches, 43 inches and 72 inches in diameter, with a stroke of 48 inches. Steam will be supplied by three boilers at a working pressure of 180 pounds per square inch.—"Engineers' Gazette."

La Lorraine.—This, the first of the new French Transatlantic steamers, has been launched, and is now being hurried towards completion. The length is 580 feet 8 inches; beam, 60 feet 2½ inches; molded depth, 39 feet 4 inches; draught, 25 feet 3 inches; and displacement, 15,200 tons. She will have five decks, with a bridge deck 340 feet long, and poop and forecastle. Like all modern steamers, she will have special cabins *de luxe* for 59 passengers. Then the ordinary first-class passengers number 378, the second-class 118 and the third-class 953, with a crew of 372. The vessel will have sixteen watertight compartments, and the double bottom will have capacity for 1,100 tons. There will be sixteen boilers of the cylindrical type, each 17 feet in diameter and 10 feet 10 inches long, with four furnaces of 3 feet 8 inches diameter, making 64 furnaces in all. The boilers will be placed in four stokeholds, and there will be bunkers for 3,000 tons of fuel. The working steam pressure will be only 165 pounds per square inch. The engines are of the triple-expansion type, with four cylinders, twin screws, of course, being adopted. The machinery space, including bunkers, occupies 58 per cent. of the length of the ship. The power is expected to work out to 22,000 indicated horsepower for the 22-knot speed. The vessel will be used as an armored cruiser, and mountings are provided for nine 5½-inch quick-firing guns and eight 1.47-inch quick-firers.—"Engineering."

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ASSOCIATION NOTES.

At the regular October meeting of this Society the following officers were placed in nomination for 1900:

For President, Commander Harrie Webster; Lieutenant Commander F. H. Bailey.

For Secretary-Treasurer, Lieutenant Commander A. B. Willits; Lieutenant W. W. White.

For Council (three to be chosen), Lieutenant Commander F. H. Bailey, U. S. N.; Lieutenant Commander W. F. Worthington, U. S. N.; Lieutenant R. S. Griffin, U. S. N.; Lieutenant B. C. Bryan, U. S. N.; Lieutenant C. A. E. King, U. S. N.; Lieutenant W. W. White, U. S. N.

Separate voting slips will be mailed to each member, with return envelopes, and it is requested that each voter give prompt attention to the matter in order that a full vote may be recorded.

A second voting slip will be mailed at the same time as the above, for the purpose of fixing upon the articles for prize awards printed in the current volume. In this connection it appears to be true that the offer of prizes does not draw out the efforts intended or hoped for. There are two suggested reasons for this; one being that of the widely scattered membership, due to the service demands. This prevents those well attended meetings, which would conduce to reviving direct interest in such matters. The second reason is that the producers of professional manuscripts in the Society find greater satisfaction in marketing their productions than in devoting their labors to enhancing the value of the JOURNAL, even with a hope of the award of a life membership together with a medal and a "purse."

At the next regular meeting, in January, a proposition will be made to again change the article governing this feature so as to do away with the prize essays altogether, and simply permit the purchase of such manuscripts, as the council may find valuable and desirable, at a fair current rate.

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We have been requested to give notice of an International Congress of Naval Architects, which will be held under the patronage of the French Government, in the Palais des Congress, of the Exposition of 1900, and opening on the 19th of July, for three days' continuance.

This congress is of interest to engineers and constructors of ships, and of motor and mechanical apparatus of every kind employed in ships, to the manufacturers of material and objects of whatever kind that may be used either in naval construction or in yards and workshops, to sailors, ship owners and yachtmen, and to everyone who is in any way concerned in the progress of maritime locomotion. All such persons are earnestly invited to help the congress with the fruit of their experience, investigations and studies. They can do this by presenting communications to be read and discussed during the sessions, by taking part in the discussions, or as listeners. The printed report of the communications and discussions will be presented to each of the active members of the congress.

Correspondence is solicited from those who contemplate aiding with papers on any branch of the subjects to be discussed, viz:

A. Naval architecture, geometry, and status of ship stability and geneneral theories.

B. Hull construction.

C. Machinery construction.

D. Special types of vessels for particular service.

E. Heavy outfitting of dock yards, etc.

F. Miscellaneous, history and development of merchant, pleasure and war vessels, etc., and including any relevant matter to marine progress or education in Marine engineering.

The Secretary-General is Mr. Hauser, Ingenieur de la Marine en retraite, 4 Rue Meissonnier, Paris, to whom further inquiries may be addressed.

A membership fee of 15 francs is fixed, and this will entitle the holder of a membership to a copy of the report of the proceedings

Persons desiring to present papers should send same before June 1, 1900, accompanied with a "brief" and summing up of conclusions.

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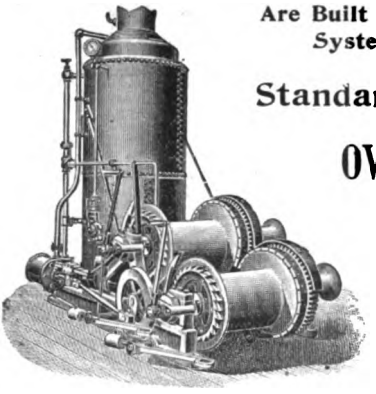

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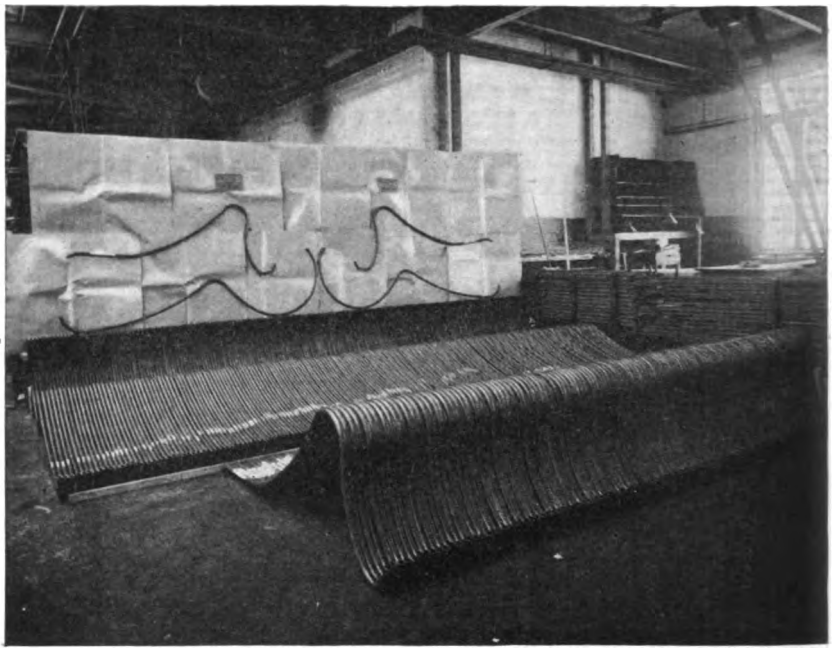

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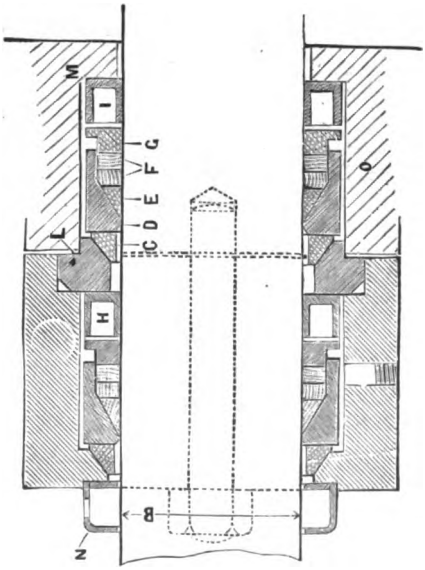

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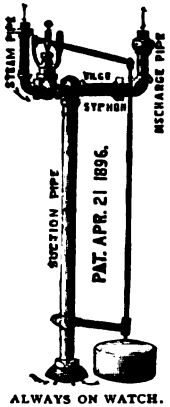

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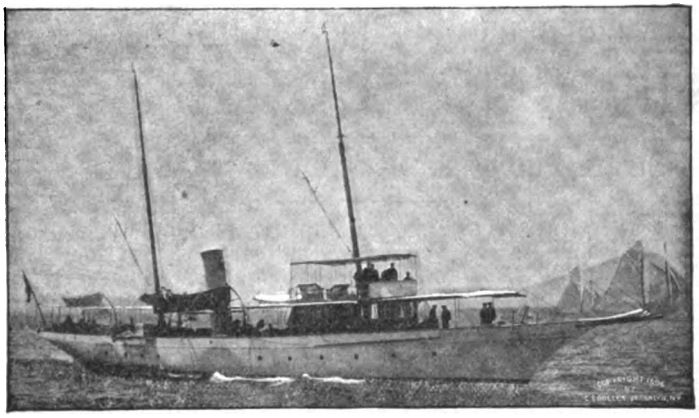

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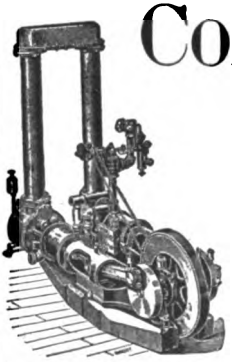

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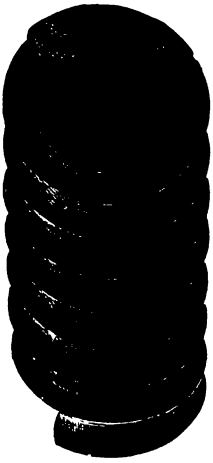

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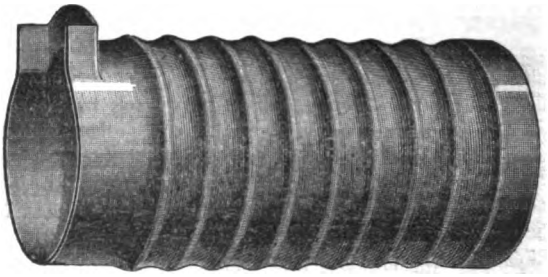

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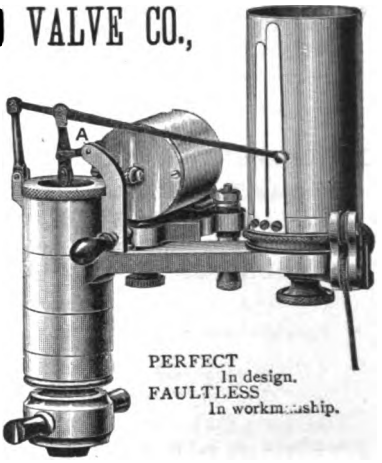

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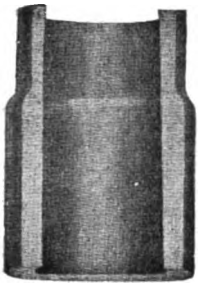
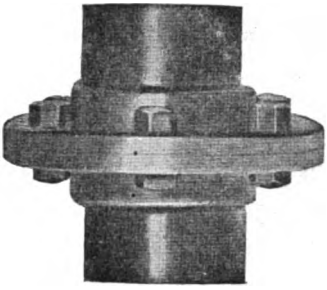
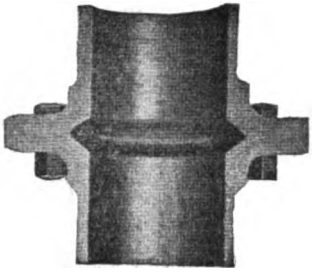


Upset Sectional View.



Upset and Flanged.



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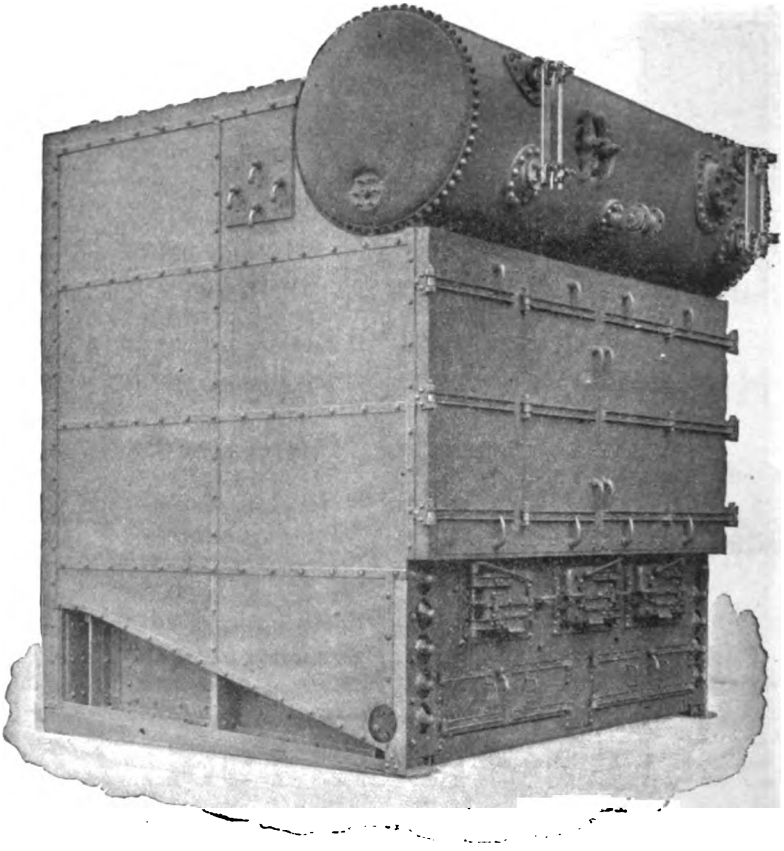

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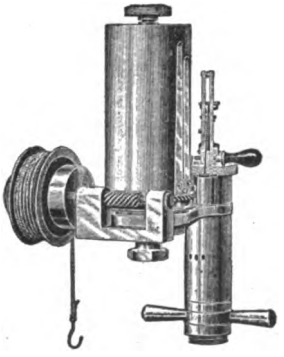

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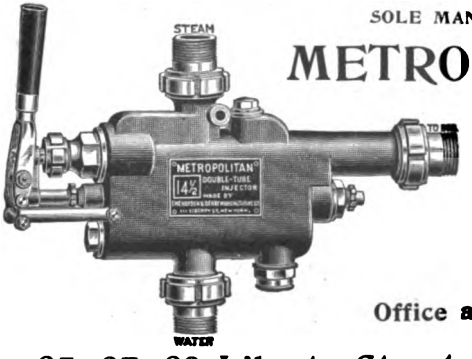

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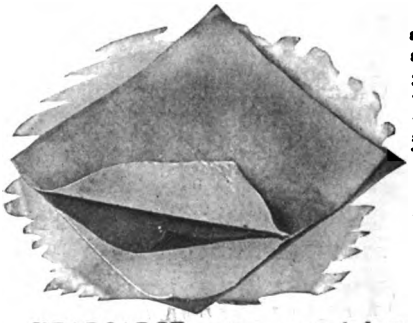

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